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Notes on the Nesting Habits of the American Robin (Turdus migratorius L.)*

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The vast area occupied by the Robin during the breeding season indicates its toleration of a wide variety of habitats. In the norther portion of its range it pushes out beyond the limit of trees where it nests in low bushes. The factors limiting the northward distribution are not clearly evident. Vegetation is important, certainly as nesting cover and perhaps as food. Along the southern limit of the breeding range the species is extending its range. In certain parts of Texas and California the Robin has moved into new areas following the establishment of a water supply by man. In the southeastern states the species is pushing steadily nearer to the Gulf of Mexico and the Atlantic Ocean, having recently reached these bodies of water in certain regions. No change in the environment seems to have preceded or accompanied this extension in the latter region.

In areas where the Robin is a common nesting bird it inhabits many diverse types of environment. The changes which man introduces seem usually to favor it. Dense forests are not unsuitable to this bird, nor are Robins absent from the treeless plains of the prairie states, but in both of these environments inhabited areas are more frequently selected than unpopulated ones.

It is in the suburban areas that the requirements of the Robin are best filled. Open lawns are very productive feeding grounds and the shade trees growing about houses and along streets are used successfully as nesting sites. The fact that this bird thrives in and about villages and towns is responsible for its great increase in numbers during the period that man has settled throughout its range.

The habitat must furnish sufficient food for the adults and their young. Many foods are eaten by Robins, but they must be relatively soft. Grains and other hard fruits cannot be digested. The habitat must provide water for in arid regions Robins occur only about sources of water. The cover requirements

*This paper is a report on a part of a study which was undertaken at Cornell University as a thesis problem under the direction of Dr. A. A. Allen. The field work on which it is based was carried out at Ithaca, Tompkins County, New York, in the south-central part of the state. Most of the field observations were secured during the years 1937 and 1938, although some data were taken in 1939. The writer wishes to thank Professor R. Chester Hughes of Oklahoma Agricultural and Mechanical College for his critical reading of the manuscript.

appear to be secondary to those of food and water for occasionally areas without trees and with little other vegetation are inhabited. North of the limit of trees nests are placed on houses or cliffs and on the western prairies nests are often placed on man made structures or on the ground.

Territory

SELECTION OF THE TERRITORY

The male seems to select the territory. Allen (1928) states that the males select the territory before the females arrive. This appears to be a flexible general rule for in the spring of 1938 some female Robins must have reached Ithaca, N. Y., before some males had established their territories. An area of about 9 acres was visited on March 18 and only one Robin was observed. This would certainly indicate that in this area, which was later populated by at least 18 pairs of Robins, the males had not yet set up their territories. Four days later a female bird banded as an adult during the preceding year was observed. On the following day, March 23, a pair of Robins was witnessed in the act of mating. It seems unlikely that the males having territories in this area established them before their mates arrived.

In 1939 a female Robin was collected on March 22 and as no songs were heard until the following day it is probable that the territories were just being established. The time at which singing is begun on the breeding ground each spring coincides rather closely with the choosing of the territory.

During 1937 eleven adults were banded in the nesting season. Five of these returned the next year to nest and in each case the nest was found. The relationship of the nests of these birds for the two years is as follows.

A female bearing band number A337123 built two nests in 1937. In 1938 she constructed a nest which was 165 ft. northeast of her first nest of 1937 and 35 ft. northeast of her second nest of 1937. In 1939 this same female built a nest 150 ft. west of the second nest of 1937. Female no. A337142 built a nest in 1938 which was 710 ft. northwest of her 1937 nest. Female no. A337141 built two nests in 1937 and in 1938 her nest was 650 ft. to the northeast of both of the 1937 nests. Female no. 37-319610 built a nest in 1938 which was 165 ft. to the east of her 1937 nest. Male no. A337199 had three nests in 1937. In 1938 his nest was only 12 ft. from the nearest nest of the preceding year, 25 ft from another, and 190 ft. from the last built of the 1937 nests.

From the above data it appears that the females return to the general vicinity of their territory of the preceding year. In the case of the male the same territory was used for two consecutive years.

There are many published records of Robins which returned to the same general locality on one or more years. The following records are based on birds which possessed some constant individual peculiarity, often of plumage.

Sage (1885) states that a Robin nested for three years in the same yard in Farmington, Conn. Another nested for five years in the same woodbine at West Roxbury, Mass. Woodsworth (1900) mentions a female present for four years near St. Albans, Vt. For two years it nested in the same yard. Thomas

(1914) writes of a bird thought to be a female which nested for several years at Kennett Square, Pa., in the same tree. Munro (1922) found that a male Robin occupied the same garden on three consecutive springs. Roberts (1932) gives records of 53 Robins banded in Minnesota and recovered a year or more later. Of these 53, eight were recovered in Minnesota, and all but three returned to the same city in which they were banded. Two of these three latter birds were banded in Minneapolis and recovered in nearby St. Paul.

The Robin returns to the same general region to nest each year. As a rule individual birds may be expected to return each spring to the same community and often the same nesting territory will be used more than one year.

SIZE OF TERRITORY

The size of the nesting territory varies considerably. If the population of birds in an area is dense and the nesting cover limited, the territory will be small. In an area used for intensive study (Area I) where there were 15 pairs of Robins in 4.25 acres, (roughly 3.5 pairs per acre) the territories were small. In one instance two concurrently occupied nests were only 18 ft. apart. In another area (Area II) which covered 9.25 acres and where there were 18 pairs of Robins, or almost two pairs to an acre, the territories were larger. In habitats where nesting cover is not so favorable as in these two areas the number of nesting pairs will be less per acre. One pair nested in a lone tree in the center of a grassy pasture of many acres. In such a case it is almost impossible to assign boundaries to the territory.

In areas where the nesting density of Robins is highest there is usually a rather dense vegetation. Such areas are not well suited to fulfilling food requirements. The dense conifers which make up most of the crown vegetation in Area I afford little food for Robins. As a consequence the feeding grounds of the pairs inhabiting this area are divorced from the nesting area.

The limits of a pair's territory can be determined by a study of their relations with other species of birds nesting nearby and with other birds of the same species. It was found by field observation that where two Robin nests were close together the line separating the two territories was roughly halfway between the two nests. This being true then a good idea of the size of the territories of a group of nesting Robins may be secured by dividing the total number of pairs in an area of suitable cover by the size of the area. Thus in Area I where there were 3.5 pairs to an acre, the size of the territory of each pair was 0.28 of an acre. In Area II, the population was lower, and the territories were larger, being 0.51 of an acre. In both of these areas the territories are probably smaller than the figures given for no allowance is made for other species using the same area. In Area I there were the following pairs of birds in addition to the 15 pairs of Robins: Mourning Dove, 1 pair; Blue Jay, 1 pair; Catbird, 1 pair; Purple Finch, 1 pair; Chipping Sparrow, 2 pairs; and Song Sparrow, 2 pairs. Thus the entire nesting population of Area I consisted of 23 pairs of birds, or, allowing all pairs a territory of equal size, an average territory of 0.18 of an acre (about 7900 sq. ft. or a square with sides of almost 90 ft.).

Butts (1927) states that the territory occupied by a pair of Robins in Ithaca consisted of a lawn and a roadside with an area of a little more than half an acre. He states that most of the food taken by this pair was secured within this area, but at times they resorted to a common feeding ground. It seems to me that this represents about the smallest territory that can fulfil all the needs of a Robin pair. In smaller territories the birds must leave their nesting territory in quest of food.

Often the feeding area, or areas, adjoin the nesting territory, but during the nesting season I have seen Robins leave a feeding area and fly away apparently toward a nest for hundreds of yards before being lost to view. This conduct indicates that the immediate availability of food supply is not the prime factor in choosing a nesting territory. The most important factor determining the location of the nest is the proper cover.

DEFENSE OF THE TERRITORY AGAINST OTHER INDIVIDUALS OF THE SAME SPECIES

Robins will usually fight with other individuals of the species which enter their territory. This is especially noticeable early in the nesting season when the limits of the territory are not well established. After the nests are built the number of fights between Robins is negligible. Still trespassers on the territory of another are attacked and driven away except in times of peril. While examining a nest I have often been scolded by four or five Robins, and once by as many as twelve. As long as the security of the nest is threatened, the owners make no attempt, or only half-hearted endeavors, to force other Robins from the territory. Once the cause for alarm has disappeared the Robins, excepting the parents, depart peaceably.

Nellis (1933) writes of two females and a male that were interested in building a nest. One of the females hindered the work of the other. The meddling bird was finally driven from the territory, and apparently crippled, by the concerted attacks of the other two.

The females are usually more vigorous than the males in the defense of the nest proper. The defense used against the members of their own species consists of dashing at the unwelcome visitor, chirping loudly, snapping the bill and erecting the feathers.

The most spirited fights that I have witnessed between Robins have taken place early in the spring when the birds are setting up their territories. One of these boundary disputes was witnessed on the Cornell Campus at Ithaca, N. Y., on April 5, 1937. My notes describe it as follows:

> Two Robins pranced about one another keeping up a continuous series of low, rapidly repeated, not unmusical notes (the excitement song or call). They fought with one another on the ground, sparred, then flew two feet up into the air fighting as they flew, striking one another with wings and bill. They alighted in a tree; fought again. Flew forty feet to another tree, never ceasing excitement calls. Suddenly one male (identification of sex based on plumage and so not certain) dived at second but was evaded. They jockeyed for favorable positions. Like a flash they came together again and flapped wildly as they rose together in the air for twenty feet. The low notes never ceased for more than a second or two. Birds moved continuously but never far. One

flew to the ground, the other followed. They began to fight again. They rose vertically for ten feet, separated and both alighted in a tree. Another scrap ended with both birds on the ground. They ran along ground for twenty feet, always keeping about two feet apart. Had two fights in which they rose five feet above ground. One combatant suddenly flew away, followed for 75 feet by the other. Latter bird alighted at that point.

These battles seem rather fierce to the onlooker, but they rarely result in injury to either participant. [However, see above note by Nellis (1933)]. On April 13, 1938, a brief but spirited fight was observed in which one Robin succeeded in pulling 3 or 4 feathers from its opponent's breast.

These brisk territorial disputes are probably not limited to males. I am indebted to Mr. Harold Axtell for the following account of a struggle between two Robins which he witnessed at Cortland, N. Y., on April 3, 1938. Two dull colored birds fought for some time, while a third bird thought to be a male watched from above them. The male took no part in the hostilities. One of the dull birds was very probably a female as it was seen to carry building material.

Often these disputes are not simple encounters between two birds. I quote as follows from my field notes for April 14, 1938:

Heard a great outburst of Robin calls. The cause was a chase in which a number of Robins took part. The birds all seemed to join in a very rapid "chir-chir-chir," etc. which had somewhat the character of a squeal. The sound seems to indicate extreme excitement. In the last few days I have often seen these chases, sometimes as many as five birds taking part and all giving this same rapid, rolling, "excitement" call.

DEFENSE AGAINST ANIMALS OTHER THAN ROBINS

Robins repulse certain species of birds from their nesting territory with determination and vigor, yet they will live in close association and in apparent harmony with others. Usually the species tolerated about the nest are of smaller size than the Robin, while those attacked are larger.

The Robin is usually bold in the defense of its nesting territory. Its reaction to the intrusion of man into the immediate vicinity of the nest varies with the makeup of the individual, the stage in the nesting cycle, and the familiarity of the birds with man. Some individuals are vigorous in the defense of their nests throughout the period the nest is being used. The female bird from nest no. 58 was both very noisy and very bold whenever the nest was visited. This female was one of the two or three Robins to strike me during the entire study of the species. A few nests were found and studied at which the parents were relatively undemonstrative, often remaining silent as the young were weighed and measured up until the young were about a week old, after which time almost all Robins scolded.

In following the nesting activities of individual pairs it was observed that their protests against the invasion of the territory grew progressively stronger. As often as not there would be no sign of a parent bird about a nest that was in the process of construction, or completed but empty. The same lack of concern is often shown by Robins whose nests contain fresh eggs. With the start of incubation most pairs will scold an intruder and perhaps dive at him.

These defensive acts increase more or less steadily until a few days after the young have left the nest.

In settled areas Robins show little fear of man, but in wild, uninhabited regions the birds are quite shy. In some of the remote sections of Maine the writer has noted that the birds are quite timid in defending their homes.

The Robin's defense of its territory against man's intrusion consists of various calls and actions. These calls are described under the section on Courtship. They usually fluff out their feathers, thus appearing to increase in size, raise the feathers of the top of the head until they seem to have a low crest, spread the tail, and flap heavily at the intruder, often hovering overhead, sometimes diving within a few feet of one, and rarely striking one with the bill although never inflicting a blow that will break the skin. The wings of the birds seem to strike together at the tips as they fly heavily overhead. It may be that this act produces a sharp sound that often accompanies this labored flight. Observation shows though that a similar sound is made by sitting birds through snapping their mandibles together. While scolding, Robins flit their wings and jerk their tails every time that they give their "chirp" note.

There are a number of references in ornithological literature to the Robin's defense of its nest against predatory species. Forbush (1929) gives an account of a band of Robins that routed a Gray Squirrel from the tree which held a Robin nest. He also writes of an instance where one Robin put two Blue Jays to flight. Roads (1932) gives an account of a Mourning Dove which drove a Robin from the latter's newly built nest. This account also records an instance in which a Robin successfully repulsed a Mourning Dove which attempted to drive it from a nest which it was relining for a second brood.

Personal observation has yielded a few instances of defense of the nest against predatory species. On May 25, 1937, a Crow was seen flying overhead with two Robins pursuing it and calling loudly and excitedly. In its bill the Crow carried what resembled a young bird. One Robin followed the Crow for 100 yards and then flew back in the direction from which it had come. The other flew twice as far before turning back. Neither Robin was seen to strike the Crow, they contented themselves with flying 5 or 10 feet away and calling continuously. This chase was witnessed in Ithaca, N. Y.

In Area I a Blue Jay had a nest which was hemmed in on all sides by the nesting territories of Robins. A few territorial disputes were noted between these two species. Victory went first to one species and then to the other. As nearly as could be determined the species nearest to its nest was always successful. On April 23, 1937, a Blue Jay was seen to alight in a large oak in which a pair of Robins had a nest. The Robin tolerated the Jay for a few minutes, then flew to within 10 feet of it when the latter flew out of the tree and away. This defense lacked the vigor characteristic of similar encounters later in the season.

On May 13, 1939, while I examined nest no. 35 the following birds were in an elm tree 15 feet south of the nest: 2 Yellow Warblers, 3 English Sparrows, and a pair of Song Sparrows. The female Robin drove away one Song Sparrow but ignored the rest of the birds. While watching nest no. 1 on April

26, 1937, I saw a Chipping Sparrow feeding in the nest tree. It passed in a semicircle about the nest only a foot from the incubating female Robin and chirped as it fed. The Robin continued to incubate her eggs paying the little sparrow no heed whatever. Nest no. 64 was visited on June 13, 1937, when it contained a young one about 9 days old. The parents repulsed a Robin which was 20 feet away from the nest, but the presence of a male Baltimore Oriole only 15 feet from the nest was not challenged.

TRAVELS OUTSIDE OF THE TERRITORY

As has been pointed out earlier the feeding area is often at quite a distance from the nesting area. It is safe to state that the Robin may travel at least a quarter of a mile in search of food. While visiting nests which contain eggs I have noticed that the male will often not put in an appearance, or that he will not reach the nest until long after his mate has begun scolding. This seems to indicate that he is so far removed from the nest as to be unable to hear his mate. Sometimes I have seen males come in to the nest flying high as if they had come from quite a distance. A banded female from nest no. 110, was seen gathering mud in Area II at a distance of a quarter of a mile from her nest.

One member of a pair of Robins was seen to follow a Crow which appeared to have a young Robin in its bill, for a distance of two hundred yards. As the Crow was high in the air and flying rapidly when the chase was first sighted it seems likely that the Robins had followed the predator for a considerable distance before I saw them.

During the evening the nesting male population of Robins on the Cornell Campus leave their nests and gather together to roost in the pines on Area I. Certainly no males were found roosting near nests, although their presence was searched for on numerous night visits. All during the nesting season Robins were seen to come to the roost from points a quarter of a mile and more away.

ABNORMAL TERRITORIAL BEHAVIOR

So little has been published on the territorial behavior of the Robin that it is not an easy matter to determine what is normal and what is abnormal. However there are certain incidents which seem at such wide variance with the usual conduct that it seems wise to group them under this heading.

Instances of polygamy represent a distinct departure from the normal. The following case seems a clear cut example of polygamy.

On April 22, 1938, I watched two females simultaneously building on nest no. 142. They went about their work with little friction between one another. In fact as the building of the nest progressed they were seen to cooperate to the extent that one stayed at the nest and placed the material which the other brought in to it. One of the two birds was heard to give the excitement call while both were on the nest. There seems no reasonable doubt that both of these birds were females and so it is interesting to know that both sexes give this call. On April 26 there were 5 eggs in the nest. As the

nest was being built on the 22nd, five eggs must have been laid in four days. On April 28 there were six eggs in the nest (later the remains of a seventh egg, and possibly an eighth were found on the ground beneath the nest.)

During incubation both of the birds were frequently observed sitting on the nest together. Sometimes one female would be on the back of the other, but more often they sat side by side. (See Fig. 1) Usually both birds spent the night on the nest together

The nest was broken up before the young left it. The females cooperated in relining the nest. On May 25, they were both on the nest incubating. The nest held 7 eggs on th 27th.

On a number of occasions during both of these nestings three birds were seen about the nest, but never four. I feel that this male had two mates.

Dr. A. A. Allen has a photograph of two Robin nests built side by side, with a common wall separating them. Both were occupied at the same time. One nest held eggs at the time the other held young.

Forbush (1929) writes of a nest found in Orford, N. H. containing eight eggs which were incubated by two females, both being on the nest at the same time. Only one male was noted about the nest.

The polygamous habit may be more common than the above three

Fig. 1. Two adult female Robins incubating their eggs in a common nest.

instances would indicate. My reason for thinking so is that there are a number of records of more than six eggs being found in a nest. The following data show that such large sets are very unusual. Mousley (1916) records that in 68 nests examined in Quebec, not a single one held five eggs or more. At Ithaca I have examined 130 complete sets of eggs and (except for the above case in which two females twice laid, between them, seven or eight eggs) only two sets of five were found, both laid by the same banded female. In none of these nests did a single female lay over five eggs. At Macwahawk, Me., on June 9, 1934, the writer found a nest containing 6 eggs, all equally incubated. A few writers state that the Robin lays as many as six eggs. The only set of seven that I have found recorded in the literature is one by Eaton (1914) which he thought was laid by one female.

In view of the above data it is highly unlikely that one female Robin can lay more than seven eggs at one nesting. Yet there are the following records of nests that held eight eggs: Keyser (1908) reports a nest containing eight eggs all of which hatched. He reports only a single female. Brooks (1933) writes of a set of eight eggs. In this case five of the eggs were white in color and three were normal. The two groups of eggs also differed in the stage of incubation. This I feel sure is a case where two female Robins laid their eggs in one nest. Forbush (1929) gives an account of two females laying eight eggs between them in the same nest. Both females incubated at the same time. Only one male was seen about the nest. No young were raised from the nest. Worth (1938) found a Robin's nest at Media, Pa., on April 26, 1938, which held eight eggs. Variations in size, color, and fertility (four eggs were infertile) were evidence that two different females each laid four of these eggs. Only two birds were seen at the nest. The writer (Worth) thought that these birds represented a mated pair and that an unmated female, which laid the four infertile eggs, was not present. Loveridge (1939) writes of a nest containing two eggs of normal appearance that were about to hatch and six white eggs that had shown slight development and then become slightly decomposed. Perhaps this is a case where one female laid six eggs and another only two. No notes are given as to the number of birds about the nest or their actions.

It may be that these instances mark the beginning of the polygamous habit in Robins. However, to my knowledge, there are no members of the Thrush family that are regularly polygamous, thus this would be a new trend for the entire family.

Throughout a single season the same two birds usually remain mated during each nesting. The pair of Robins from nest no. 1 raised three broods together in 1937. However, Forbush (1929) presents a case where a female Robin changed mates. No evidence is given that the former mate in this case may not have been killed.

The dense nesting population, so common among these birds, may be a factor in bringing about polygamy.

If the number of female Robins was greater than the number of males this might induce polygamy. However, in the birds that I have sexed, the number of males is equal to that of the females.

In these cases of polygamy the parental unit becomes a trio rather than a pair. Thus they represent an exception to the usual territorial behavior where one male and one female tolerate no trespassing by other Robins of either sex. This weak defense of territory is also demonstrated by an episode recounted by Forbush (1929), where the three young of one pair were fed by a female who played no part in the earlier history of the nest.

All data considered it seems that there are never two males in one territory, but that on rare occasions one male may have two mates; or a second female may be allowed to enter the territory to assist in caring for the brood.

The above data relate to unusual territorial relations between Robins. There are numerous notes on unusual behavior involving Robins and other species. Robins have been recorded nesting in close association with the following species:

Mourning Dove—Raney (1939) writes of a case where a Mourning Dove and a Robin both laid in the same nest and both shared alternately in the process of incubating the eggs. Both parents fed the young, but at different times. The matter is the more remarkable in that both species used the same nest together on two consecutive years (1933 and 1934). While no hostilities were observed it was probable that the relations were not always amiable as the remains of a Robin egg were on the ground beneath the nest. Furthermore both species did not incubate at the same time.

Kingbird—Morse (1931) writes from Wisconsin of a nest of this species only 14 inches from a nest of a Robin. Both nests were occupied at the same time and both species raised a brood.

Tree Swallows—Munro (1929) has a note on the feeding of young Robins by a male swallow. The swallow had a brood of young in a nesting box on top of which the Robins had a nest in which there was a brood.

House Wren—Metcalf (1919) recorded an instance of this species nesting in a bird box on top of which a Robin had a nest. Harmony prevailed between the two species in spite of the House Wren's habit of puncturing the eggs of birds that nest nearby.

Catbird—Wetherbee (1930) found a Robin nest in a clump of lilacs a few feet above a nest of the Catbird. The Robin was seen to incubate the eggs of the Catbird at times and also to help with the feeding of its young. The part played in the Robins' nesting activities by the Catbird was not determined as the Robin nest was not found until too late.

Bluebird—Handley (1927) published an account of a Robin nest on top of a bird box occupied by this species. Relations were hostile but the Bluebirds could outfly the Robins. The Bluebird was seen to feed the young Robins during the absence of the parents.

English Sparrow—Jones (1896) reports that a pair of these birds selected a site already occupied by a Robin nest containing four young. The sparrow's nest touched that of the Robin. Both species raised a brood normally. Jensen (1925) tells of Robins being so tolerant of this species that the sparrow was able to steal food from the throats of its young.

House Finch—Bailey (1936) gives an account of a community nest which contained 4 half-grown young Robins, 2 newly hatched finches and 4 finch eggs during May 1934. The species building this nest was not mentioned. Both the adult finches and the Robins fed the young. On May 15, 1936, he noted another nest containing young Robins which were being fed by both House Finches and Robins.

Redstart—Allen (1925) recounts the strange case of a pair of Redstarts which fed a brood of Robins. The young of the Redstart were placed on the hand of Dr. Allen's daughter. The male Redstart alighted on the girl's hand and fed its young, but the female Redstart was not bold enough to do this and satisfied her instinct to feed young by placing her bill full of green "worms" in the mouth of a young Robin 25 feet away. This action was repeated a number of times by the female Redstart who even went so far as to protest the presence of the parent Robins when they returned to their nest. Later the young Redstarts were placed in a cage where they could not be fed and the male Redstart then also began to feed the young Robin. This episode occurred at Ithaca, N. Y., in the summer of 1925.

Courtship

The courtship of birds consists of their actions just prior to and including mating. It is the process by which a bird secures a mate. Little appears in print concerning the courtship of the Robin, although Forbush (1929) comments on the fact that it is done in public where all may witness it. He further mentions the apparent indifference of the female.

My field notes contain little that may definitely be labeled courtship behavior. The following notes were made on April 14, 1937, at 7:00 A.M. on a clear day when the temperature was about 50° F. These observations were made in a mixed coniferous and deciduous woods on the edge of Cascadilla Creek, in Ithaca, N. Y.

One male's singing seemed to attract a female who came within 40 feet of him and sat in a tree. She chirped a few times. He ceased his warble (full song) and adopted a new song—a chain of metallic, beadlike notes, less in volume and lower in pitch; the pitch remained quite stable. [This I take to be the mating song mentioned by Saunders (1922)]. After perhaps 5 minutes the male flew closer, still singing. In the end they were in the same hemlock, the female having moved only 5 feet in the direction of the male. The male began to display at a distance of 3 feet from the female. This display consisted largely in expanding the tail and lifting it until it was held slightly higher than the head. After about 5 minutes of display the male flew to the ground beneath the tree (both birds were about 6 feet up). Here he continued his display looking up now and then to see if the female were attentive. A few minutes later she joined him on the ground and the display continued about three minutes. Then the male flew to a bush. The female flew to a bush in another direction and they manifested no further interest in each other. At one time during the proceedings a third bird put in an appearance, but left without causing a disturbance.

The sex of these birds was not determined with certainty; appearance and behavior were used to separate them.

This same male had an encounter with another Robin. In this case the newcomer alighted in a hemlock near where the male was singing. He stopped singing and flew into the hemlock. A few seconds later the intruder flew away.

In this case there was no display, nor was there a fight. Presumably the singing bird repulsed a rival male from his territory, although the incoming bird may have been a female that did not excite him to display.

On this date a few Robins had their nests built, but many pairs had not begun to build their nests and others seemed not to have chosen mates.

In the works of Audubon (1856) alone have I found an account of the courtship of the Robin. Here is his description:

> During the pairing season, the male pays his addresses to the female of his choice frequently on the ground, and with a fervour evincing the strongest attachment. I have often seen him, at the earliest dawn of a May morning, strutting around her with all the pomposity of a pigeon. Sometimes along a space of ten or twelve yards, he is seen with his tail fully spread, his wings shaking, and his throat inflated, running over the grass and brushing it, as it were until he neared his mate, when he moves around her several times without once rising from the ground. She then receives his caresses.

Audubon's report shows that the courtship which I recorded was not complete. Probably the pair I observed were not far enough along in the reproductive cycle to go through the usual full courtship performance. This very likely represents the attempt of a male to secure a mate. The male made no use of his wings and he did not inflate his throat. Nor did courtship end in copulation. Audubon makes no mention of the part played by the voice in courtship. It seems certain that this low song plays an important part in the courtship of the Robin for it is often heard when the two sexes are close to one another. It should be remarked, however, that this same song is used by both combatants in territorial battles. I propose calling this the excitement call or song as it is not always associated with mating.

My observations on the copulation practices of the Robin are few. This act was witnessed on April 25, 1937. My notes read: "10:00 A.M. Observed a pair of Robins copulate 4 times in less than 2 minutes. The act took place on the ground, 50 feet from nest no. 21. Then female flew to nest tree and male followed as though mating were being attempted. A few seconds later female flew to the ground 30 feet east of nest followed by male. They mated again. All this took place in a period of not over 8 minutes." Nest no. 21 was examined and found to contain one egg.

The part played by the bird's voice in courtship behaviour is very important. The singing of the male serves to acqaint the female of his whereabouts. My notes above show that the voice is used by both sexes. When the female first alighted near the male she was heard to give a few chirps which served to attract his attention. After he had approached the female the male gave the excitement song.

During the courtship period fights are numerous. In no case have I seen any indication that fighting is directly concerned with courtship. Squabbles between Robins do not end in mating between the fighters and so it seems that disputes are not between males and their mates, or prospective mates, but in defense of territory.

Robins were often witnessed to fly after one another but these chases were

never observed to end in mating. Thus it appears that these pursuits were not a part of courtship, but were the climax of a territorial altercation.

Owing to the prominent part played by the voice during the courtship period a general account of the songs and the calls of Robins is given at this point.

Song

Excellent descriptions of the song are given by Saunders (1935) and Matthews (1904).

VARIATION AMONG INDIVIDUALS

Many ornithologists state that they can recognize small peculiarities of song pattern, quality, or pitch that distinguish the song of one Robin from that of all others in the same area. Saunders (1935) mentions this. Mathews (1904) gives a graphic account of individual Robin songs. Bicknell (1884) also attests this fact.

VARIATION IN THE SONG OF AN INDIVIDUAL

Not only do the songs of individual Robins vary, but Bicknell (1884) calls attention to the fact that the same individual will render its songs differently from time to time.

TIME OF DAY AT WHICH ROBINS SING

The Robin is one of the first birds to begin singing in the morning, being preceded only by the Song Sparrow and the Chipping Sparrow according to Wright (1912). I have heard them begin to sing when I was yet unable to be certain that day was breaking. The first Robin to clear his pipes will often have a minute or two of the morning silence to himself before the morning chorus begins in earnest. This chorus lasts from thirty to forty-five minutes after which there is very little song for a time. Allen (1913) states that the average time at which Robins first began to sing on 18 days was 3:04 A.M. These records lie between May 29 and July 26, and were made at Boston, or nearby. This writer disagrees with Wright in the latter's statement that the Song and Chipping Sparrows precede the Robin, his records showing that the Robin is the first bird to be heard in the morning.

During each day there are two outstanding periods of song. One is in the early morning before the sun's rise and the other is in the evening twilight following sunset. The daylight hours separating these periods are marked by a reduced volume of singing, with the low point coming about noon.

On the evenings of April 28 and 29, 1937 observations were made on a group of between one and two hundred Robins which roosted in a small patch of conifers on the Cornell Campus. On the former evening the Robin chorus ceased at 7:40 P.M. The following evening the singing closed at 7:45 P.M. The evening was cloudy on the 28th and clear on the 29th; sunset was at 6:55 and 6:56 P.M. respectively. Wright (1912) noted that a Robin was last heard singing at 8:18 P.M. when the sun set at 7:30. He found that the Robin sang

later than any other species. Thus the Robin has the longest period of musical activity of the common songbirds.

The relationship between the time at which the Robin gives its last song for the evening and the intensity of light has been worked out by Shaver and Walker (1931). Their findings show that there is a close correlation between these two factors—much closer than for the mockingbird on which they also worked. They found that an even closer parallel existed between the time of sunset and the time at which the last song was heard.

Roberts (1932) has this to say of night singing:

> The Robin may, rather rarely, sing in the middle of the night. "Minneapolis; June 2, 1878. Last night about twelve o'clock, when it was cloudy and very dark, a Robin was heard singing in some trees across the way. It sang or rather warbled for some time, stopping occasionally and then commencing again. At the same time a cuckoo was sounding its notes in a nearby yard" (writer's journal). This night song resembles the "whisper song" of the mating season, which the Robin possesses in common with most singing birds.

Allen (1930) also writes of Robins singing at night.

SEASONAL VARIATIONS IN SONG

The first songs of the Robin in late winter or early spring seem to possess most of the volume, length, and richness of tone that are heard later in the spring. The period of courtship is the time at which the greatest number of individuals are singing and also the period during which the song is most rich and full. With the coming of nesting cares the male seems to continue singing with little let-up until the young are hatched. At this point Saunders (1935) says that he ceases to sing. Certainly he does sing up until the eggs are hatched for on May 13, 1939 I made the following entry in my journal: "10:00 A.M. Saw a Robin sitting on the edge of a nest and singing. He sang his full song a few seconds, noticed me watching him from the path 35 feet away and was silent. A minute or two later he sang once again (his full song) then flew to a nearby maple where he continued singing." The nest was climbed to at 8:10 P.M. and found to contain one young just hatched and three eggs. At no time did the singing bird settle on the nest hollow.

While it seems to represent abnormal behavior, at times males do sing when there are young in their nest. The male from nest no. 41a was heard to warble a few notes on May 26, 1937, when the four young in his nest were a day old. After his short burst of song the male carried food to the nest and fed the young.

On July 29, 1939, the male of nest no. 249 sang twice, and with almost average volume. On this day there were three young in his nest that were eleven days old. As this bird fed the young his connection with the nest seems beyond question.

Gabrielson (1922) reports that a male whose nest held two young about to leave the nest, sang often and played no part in feeding the young. The observation was made on June 30, 1913, at Sioux City, Iowa.

Soon after the young leave the nest the male begins to sing again. As the

times at which Robins have young in the nest are staggered throughout the nesting season there is no period at which no males are singing. Those pairs of Robins which raise three broods sing during the early part of their final nesting. On July 3, and again on the 10th, the male of a pair in which the female was banded, was heard to warble. The nest of this pair was just built on the former date and held three eggs on the latter. This pair was known to have raised two broods prior to this time.

During late July and August when most Robins are molting there are fewer birds singing and the songs of individuals become progressively shorter and lose volume. Fry (1916) shows the progressive decline in volume of the song of the species. There is little singing during September except at the end of the month when there is often a renaissance. Bicknell (1884) has this to say of the song during this season:

> The secondary song-period is introduced with much regularity in different years in the last days of September. From 1878-81, my record runs: September 27, 26, 28, 25, but unfavorable weather may postpone the beginning of the second song-period until October. The first songs are usually subdued and broken, but soon acquire the normal character, and sometimes continue with little interruption through the month of October; but again there may be an almost complete intermission between the first or second and final week of the month. Sometimes when this is the case, multitudes of birds arrive from the north about the third quarter of the month, bringing song with them, and in the last week if the weather be damp and cloudy, numbers may be heard singing with almost the freshness and vigor which characterizes their song in April.

Bicknell continues by giving the last dates on which Robins were heard to sing. These fall between October 21 and November 8. At the time the last songs were heard the majority of the Robins had passed southward in migration.

Numerous references in the literature point to the fact that some Robins are in song throughout the winter. Black (1932) reports them singing in a roost at Winslow, Arkansas, on October 30 and November 7. Many more were singing on the first than on the second date. Chapman (1888) writes of Robins observed at Gainesville, Florida, that they were abundant and in full song until December 31, no songs being heard later. Lacey (1911) in observations made on birds at Kerrville, Texas, states: "They sing here all winter when the weather is mild." Wright (1902) states that Robins gave "cheerily" notes at Cambridge, Mass., on January 7 and 8, 1902. Angus (1932) reports a large flock of Robins singing near Quincy, Ill., on January 10.

Baerg (1930) has many interesting data on the winter singing of Robins in northwest Arkansas. He lists the following dates on which singing was begun: 1925, February 1; 1926, January 20; 1927, January 31; and 1928, January 11. He heard a Robin sing on December 26, 1926. "In the Robin roost, near Winslow, the song will probably be heard quite regularly during November and possibly later." He also writes: "The Robin winters here in small numbers. Apparently the earliest singing is done by winter residents. The early morning chorus begins later, when the Robin becomes more numerous about February 10."

Owing to the fact that the Robin is usually silent on first reaching its summer home it seems that as a rule it does not sing on its wintering ground.

However, from the records given above it is evident that they do so at times.

The male Robins precede the females in spring migration. It is difficult to be certain when the first females arrive. However, I am certain that in 1939 the arrival of the females was prior to the first singing of the males. A female Robin was collected on March 22 and the first song was heard on the following day. In 1938 the reverse seems to have been true for the Robins reached Ithaca in some numbers about March 10th and were singing by the 13th. The first bird known to be a female (banded) was not seen until the 22nd.

In as much as Robins do not set up their territories as soon as they arrive on the nesting ground it is probable that the beginning of singing coincides roughly with the choosing of a territory, and that both of these activities have their start at approximately the time the females reach their summer homes.

SEX SINGING

Cases in which female birds possess the ability to sing are few. There is no evidence that I have come upon that female Robins sing. They do, however, give numerous calls.

SONG PERCHES

Allen (1930) mentions that Robins become attached to certain song perches—a gable, a tree, or the like. Usually the song is given from a point of vantage, the top of a tree rather than a lower branch, but my field notes contain references to birds singing from almost any situation. Some sing from the lower branches of a tall tree, some even on the ground. One sang from the level surface of a clean-cut athletic field. Another sang from an iron post only two feet high, when by flying a few feet in almost any direction he could have secured a more prominent position. The Robin may have a song perch which he prefers to all others, but he by no means limits his singing to it.

CALLS

The Robin produces a wide variety of calls and notes. I have experienced some difficulty in classifying and describing them. Furthermore it is confusing to make comparisons with the calls and notes recorded by others, as few people describe the same note in the same terms. When possible I have compared my descriptions with those of other observers.

Perhaps the most commonly given note is a spirited "chirp." This is the "yeep" of Saunders (1935). Forbush (1929) calls it an alarm note and states that it is ".... varied in pitch and volume from low to high and shrill." It is given throughout the year. When given loudly it certainly functions as an alarm note, but at other times it is rather soft and at such times there will be no obvious cause for alarm. When the birds are disturbed about the nest both sexes use it to protest against intrusion. Usually, at such times, it is followed by a lower note which sounds to me like "cuck." The latter note is often repeated a number of times. In scolding the loud "chirp" is repeated with great frequency and with each repetition the tail is usually jerked up. On

May 20, 1937, I noted the number of times that a female gave this "chirp" during one minute periods. The bird had young a day or two out of the nest nearby. The count ran as follows: 50 times in the first minute; 49 in the 2nd; 56 in the 3rd; 53 in the 4th; and 52 in the 5th. The "cucks" interspersed here and there were not counted. This bird was not more than average in her frequency of protest.

Another call which is frequently given sounds to me like the word "chirr" repeated rapidly five or ten times and growing in intensity and rising in pitch. This call varies greatly in pitch and when given at a higher pitch it sounds like "chee." Saunders (1935) refers to this as a laugh and represents it this way—"ha-ha-he-hi-hi-ha-ha." This call is given under a number of conditions, but usually when the bird is in no danger and often at seasons when Robins are in groups. It may be associated with sociability or a sense of well-being.

Saunders (1935) writes of a note with which I am unacquainted. It is "a high-pitched, faint, whining 'eeeee' which strongly suggests a Cedar Waxwing." Forbush (1929) also lists "a thin lisping note much like that of a Cedar Waxwing."

During the night of June 6, 1937, I captured a female Robin on her nest. She gave a prolonged, loud, high-pitched, rather hysterical squeal. This was a note of despair or intense fear.

Forbush (1929) gives an account of the following calls, that probably represent in some cases variations of those already treated. ".... a soft, ventriloquistic *kwee-kwee-kuk*, or *kwee-kwee-kuk-kuk-kuk*, a sharp clear, high, sparrowlike *chiepp;* a short *tut-tut*, with a jerk of the tail; rapid, rather explosive *puck-puck-puck-puck-puck*, with a jerk of the tail at each syllable; *sheek-sheek;* a clear *tee-urp* (G. F. Simmons); *'wicky-wicky-wicky'* (O. W. Knight); also very low conversational chattering, chuckling, etc."

Nest

NESTING SEASON

Throughout its range the Robin is one of the earliest passeriform birds to begin nesting. Nest building may start long before the eggs are laid. Nest no. 120 was in the middle of the mud layer in its construction on April 1, but the first egg was not laid in it until April 15.

The nesting dates have been organized on the basis of latitude. The breeding range has been divided up into bands of ten degrees of latitude. Within each of these bands the dates are listed from east to west. Robins inhabiting regions of the same latitude usually nest at about the same time.

The records chosen are those which give a picture of the beginning or end of the nesting season. The purpose being to outline the duration of the season and not to give a mass of dates scattered throughout the entire season. In the area north of 50° of lattitude some of the records do not represent the true beginning or termination of the nesting season for few workers have spent the entire nesting season so far north. But the records used are the only ones available.

NESTING DATES FOR THE REGION BETWEEN THE 30TH AND 39TH DEGREES OF LATITUDE

Georgia—Clayton, Rathbun Co., Burleigh (1925) found a nest with three eggs on April 13, 1922, and a nest with four eggs on the 14th. On both of these dates there were other nests found that had just been built.

North Carolina—Western North Carolina, Oberholser, H. C. (note in Fish and Wildlife Service files) records the season as extending from March to July.

Virginia—Montgomery Co., Smyth (1912) lists fresh eggs as early as March 20, in 1900.

Illinois—Philo, Champaign Co., Hess (1910) gives the extremes as April 19, 1897, 4 eggs, and July 18, 1908, 4 eggs.

Oklahoma—Cleveland Co., Nice (1931) lists 77 nests of the Southern Robin, earliest 4 eggs on March 23, 1921, 10 nests with full sets of eggs by the end of March, 1921. Usually nests are built the first week of April. Latest nest held large young on August 24, 1926.

Kansas—Doniphan Co., Linsdale (1933) gives the extremes of the season as May 15 and July 16.

Colorado—Denver Region, Dille (1903) states that the average date for fresh eggs is May 22. Mesa Co., Rockwell (1908) reports it nesting during May and June. Elk Mountain Region, Gunnison Co., Warren (1916) writes that nesting begins in May and June, and young are hatched by the end of May and early June.

California—Dawson (1923) states that the nesting season for the state as a whole lies between April 15 and July 10.

NESTING DATES FOR THE REGION BETWEEN THE 40TH AND 49TH DEGREES OF LATITUDE

Pennsylvania—Allegheny Co., Burleigh (1923) lists the earliest set of eggs as April 14, 1912.

Pennsylvania and *New Jersey*—Harlow (1918) writes that the earliest date for fresh eggs is April 18 and the average as April 20. These dates are based on 346 nests.

New York—Eaton (1914) writing about the entire state says that fresh eggs are commonly found between April 22 and May 8. In one exceptionally early season he found a nest with fresh eggs on March 31. He states that a third nesting period is often started from the first to the nineteenth of July.

Table 1 shows the distribution of nesting records throughout the breeding season at Ithaca, N. Y. For 1937 my records are complete for the season; in 1938 I was not in Ithaca from June 15 until July 20. The earliest complete set in 1937 was one of four eggs on April 21, and in 1938 it was one of four eggs on April 17. In 1937 the height of the second nesting season lay between May 26 and June 4 for fresh eggs, and the third sets were laid between July 5 and 14. The pair building nest no. 1 had fresh sets on the following dates: April 21, May 28, and July 9. The pair building nest no. 2 had fresh sets on these dates: April 26, June 1, and July 10. Both of these two pairs brought forth broods successfully on each attempt.

Rhode Island—Forbush (1929) gives the season as from April 17 to July.

Connecticut—New Haven, Bishop (1921) lists an instance where there were young a few days old in a nest on September 1, 1919.

Massachusetts—Hingham, Pope (1908) reports a Robin building on August 4, this nest held young 2 or 3 days old on August 23. Forbush (1929) gives the season for the state as a whole as lying between April 12 and July 25.

New Hampshire—Jefferson Highlands, Wright (1918) gives an account of young which left the nest August 27, 1917.

Maine—Forbush (1929) gives the limits of the season as April 28 and early August.

Minnesota—Roberts, T. S. (1932) in his work on the state as a whole gives the

TABLE 1.—Nesting records of American Robin at Ithaca, N. Y. Nesting season is divided into periods of ten days each. Date assigned to each record is that on which first egg of clutch was laid.

Periods	Number of records 1937	1938	Totals
April 6-April 15	0	4	4
April 16-April 25	2	25	27
April 26-May 5	16	18	34
May 6-May 15	9	13	22
May 16-May 25	9	10	19
May 26-June 4	16	4	20
June 5-June 14	6	0	6
June 15-June 24	3	0	3
June 25-July 4	4	1	5
July 5-July 14	4	1	5
July 15-July 24	1	1	2
July 25-August 4	0	0	0
Totals	70	77	147

nesting season as from April 10, 1912, to August 22, 1922, when the young left a nest.

South Dakota—Sioux Falls, Larson (1925) gives the earliest nest with eggs as April 25, 1908.

Oregon—Fort Klamath, Merrill (1888) states that many nests had full sets by May 1.

NESTING DATES FOR THE REGION BETWEEN THE 50TH AND 59TH DEGREES OF LATITUDE

Quebec—Fort Chimo, at 58° latitude, Macoun and Macoun (1909) write of a set taken on June 13 by E. Bouchier, Great Whale River, at about 55°. Eifrig (1906) records a nest found on May 24, 1899.

Manitoba—Fort Churchill, at 58°, Taverner and Sutton (1934) report that the first complete set of eggs was found on June 6, 1931.

Alberta—Medicine Hat, at 50°, Macoun and Macoun (1909) write of the first eggs being laid on May 22, 1894. Edmonton, at 53°, the above authorities report that nest building starts by May 6; eggs hatch in early June.

Alaska—Haines, at 59°, the above authorities give an account of a bird on four well incubated eggs on June 2.

NESTING DATES FOR THE REGION BETWEEN THE 60TH AND 70TH DEGREES OF LATITUDE

District of Mackenzie—Fort Smith, at 60°, Preble, E. A., reports young on the wing from June 19 to 28 (note in Fish and Wildlife Service files). Fort Anderson, at 69°, MacFarlane's catalogue of specimens records sets of eggs taken on June 3 and 16, 1863 (F. and W. S. files). East branch of the Mackenzie delta, Stefansson (1913) tells of a nest and four young on June 22.

Alaska—Fort Yukon, on Arctic circle, Kennicott in his register of specimens lists a nest with eggs on June 9, 1891. Nome at 64°, Bailey, A. M. (1926) found eggs on June 21.

NEST SITE

SEX SELECTING SITE AND BEHAVIOR DURING SELECTION

Both birds of a pair work together in selecting the site for the nest.

On May 5, 1937, Mr. Harold Axtell, of Cortland, N. Y. observed a pair of Robins selecting a nest site. The male worked with the female in searching for a suitable site. But when the site was selected the female did all the building.

Samson (1923) reports from Maumee, Ohio, the actions of a pair of Robins that were choosing a site for their nest in his yard. They were seen to investigate a variety of sites before choosing one on a rain-pipe. They did not start building at once, but were building later in the same day.

Jordan (1901) of Bethel, Me., witnessed a pair choosing a nest site on a morning in late April, 1900. They kept flying from branch to branch examining a number of sites. Having decided on a certain location this pair began at once to build. The male experienced some difficulty in flying into the nest site and finally both birds abandoned it for a more accessible place.

A fine account of the procedure used in selecting the site for the nest is given by Meuli (1935). I quote his notes in their entirety:

The maneuvers of a male and female Eastern Robin *(Turdus migratorius migratorius)* in several large American elms, approximately eighty feet in height, were noticed on the morning of April 15, 1935, in St. Paul, Minnesota. The day was cloudy and cool and sufficiently early in the season that no foliage hampered observation of the birds in the trees.

They were seen to flit from one crotch to another in a very random manner, until the entire tree was inspected. Occasionally one bird would fly to an adjoining tree and shortly return to be near its mate. The greatest interest lay in the procedure followed at each visited crotch. The bird would spread its legs in order to support itself with one foot on each side of the conjuncting limbs and in this position it would crouch and shift its weight from side to side, and at the same time ruffle its feathers and slightly extend its wings. After several seconds it would reverse its position and repeat the process. In no case did this procedure consume more than a minute's time. The routine appeared to be so similar to the characteristic shifting and turning observed during actual nest building and after nest completion, that it was immediately believed that these birds were giving trials to various sites for their nest.

The Robins evidently preferred to start at the lower branches of the trees, which were twenty-five feet above the ground, and gradually work their way upward until they were approximately fifty feet from the surface of the ground at this point the limbs had a tendency to thin and branch out. This was apparently a characteristic without appeal to the birds, for at that height they left with a downward flight to begin over again in an adjoining elm. The birds disappeared after completing their trials but on April 29, when the trees were visited for observation, a partially completed nest was seen in the last elm. As closely as could be determined, the crotch, the conjuncting limbs of which were about five inches in diameter, was approximately fifty feet above the ground and formed an angle of about fifty degrees. This is the vicinity in which the birds were last seen during their hunt for a nest site. While the evidence is not positive that the present winged occupants, which at the moment were busily chasing sparrows from the tree, were the birds seen previously, the likelihood is great, for no other nest of any other species could be seen in the neighborhood.

In this case the birds did not begin their nest as soon as they had chosen the site.

Forbush (1929) writes on this subject as follows:

Probably the female usually chooses the nesting site but sometimes the male is insistent of his own choice. Mr. L. P. Marden of Weymouth, Massachusetts, says that a male Robin tried to persuade a female to occupy his last year's nest, even going so

far as to bring material himself and begin to repair the old home, but she would have none of it, and built a nest in a cedar further away from the house.

DISCUSSION OF NEST SITES

The Robin has remarkably plastic nesting site requirements. The nest is sometimes on the ground, or it may be eighty feet above the ground. A tree is usually chosen for the nest but almost any object which will support a nest may be used. Many nests seem to be built without regard to concealment although the usual nest is partly concealed and elevated beyond the easy reach of predators. The comparatively low nesting success of this species during the first nesting period is due in no small part to its frequent choice of sites that offer poor protection.

Many of the sites selected by these birds do not offer secure anchorage for the nest. A number of nests that I have had under observation have fallen to the ground, or become so tilted by the wind, rain, or the weight of the parent on the rim, that the contents have spilled out. In one instance a female Robin persisted in an attempt to build a nest on a ledge, of a building, that was too narrow to support the nest. This female was seen building on her nest on May 1, 10, and 23, 1938. On the latter date there was a great mass of dead grass and other material on the ground beneath the ledge. This bird never succeeded in her attempts to build a nest here.

About Ithaca the Robin most often builds its nest within ten feet of the ground. Of 244 nests examined in the years 1937 and 1938, 122 were not over ten feet above the ground. None was on the ground. The highest was 65 feet above the ground. The following data give the number of nests found in various intervals of height.

Height	Number of Nests
2-10 ft.	122
11-20 ft.	62
21-30 ft.	35
31-40 ft.	20
41-50 ft.	2
51-60 ft.	2
61-70 ft.	1
	244

The relationship between the location of the nest and the trunk of the tree is variable. In trees which possess a spreading type of growth such as lilacs, dogwoods, elms, etc. there is often no definite trunk, but with trees having a strict type of growth such as most conifers a trunk is evident. Where there is a well-defined trunk the nest is usually placed against it. Thirty-three nests found in trees having a strict type of growth were used as a basis for determining the relation of the nest to the trunk. Twenty-six of these nests were against the trunk, four were within 5 feet of the trunk, two between six and ten feet of the trunk, and one was fifteen feet from the trunk.

During the first nesting period the Robin displays a marked preference for evergreens. At this time many of the deciduous trees are without leaves. When the birds begin building their second nests, after having raised one

brood, they choose deciduous ttrees more often than they do evergreens. Below in table 2 are given data for the sites used for the two, or three, nestings of the Robins about Ithaca during 1937. The first nests listed below are those built between the opening of the nesting season and May 15. The later nestings include all those built after May 15. Many nests were constructed on buildings, the arms of telegraph poles, tops of bird houses, etc. This latter group of sites have been put under the heading of nests not in trees.

TABLE 2.—Nest sites used by Robins for first and subsequent nestings.

Nest Site	No. of Nests	Percentage
First nests in evergreens	34	57.6
First nests in deciduous trees	15	25.4
First nests not in trees	10	17.0
Totals	59	100.0
Later nests in evergreens	23	38.3
Later nests in deciduous trees	29	48.3
Later nests not in trees	8	13.4
Totals	60	100.0
Season's nests in evergreens	57	47.9
Season's nests in deciduous trees	44	37.0
Season's nests not in trees	18	15.1
Totals	119	100.0

When a Robin's nest is broken up, or abandoned by the parents, another attempt is made to raise a brood except when the mishap occurs at the latter end of the nesting season, when a renesting may not be attempted. Sometimes the parents will use the first nest again, in spite of their misfortune. The three Robins using nest no. 142 had their brood destroyed about May 13, 1938, and on the 19th both females were at work relining the nest. They later laid eggs in the nest. Usually when a nest is broken up the parents will move to a new site. Such changes rarely take them over 200 feet from the original site and the usual distance is about 50 feet.

Mousley (1917) took three sets of eggs from one pair. The three nests were within 45 feet of one another. After the third set was taken the pair disappeared. In each case ten days elapsed between the collecting of one fresh set and the next.

The tenacity with which Robins stick to a nest site is well illustrated in an account given by Allen (1878). In Cambridge, Mass., a pair of these birds began building a nest in a tree in a yard. The owner of the yard thought the nest was placed so near the ground that a cat would surely destroy it, and he removed the completed nest, hoping that the parents would build again in a safer place. Four times he removed nests built by this pair in the same place. They built a fifth nest that was not molested by the owner. Gault (1898) writes of removing a Robin nest from a window ledge. The female laid an egg on the ledge. At the close of the day the nest was replaced and the egg was put into it. A brood was raised. Roberts (1920) tells of a Robin's nest that was removed from the ledge of a house and burned. An egg was laid on the ledge. A last year's nest was put in the place of the new nest that had been destroyed and the egg put into it. The bird removed the egg, repaired the nest, and laid

another egg, all in one day. Eves (1923) records the fact that a Robin's nest that was one-third completed, was moved from its position on top of a hanging dishpan and placed on a nearby shelf. The parents completed the nest and raised a brood in it.

Accounts of unusual sites for Robin nests are common in all works dealing with ornithology. Some of the more interesting are given below.

Mearns (1879) quotes Lieutenant Willis Wittich as saying that on the prairies in Oregon Robins build their nests on the ground or in timber near the ground. Miller (1918) of Springs, Pa., gives an account of a nest of typical construction in clover on the ground. It contained four eggs. Blincoe (1924) reports the finding of a nest on the ground under a rhubarb plant in a garden at Dayton, Ohio. Allert (1925) writes of a nest on the edge of a deep cut road which was partly supported by exposed elm roots. Christmas (1925) found a nest at Delanson, N. Y. on the ground at the base of a button-bush clump. An occupied nest of Song Sparrow was only a foot away on the other side of the clump. Thoms (1929) gives photographic evidence of a particularly odd site. The eggs were on some leaves near a house in Vermilion, S. D., with ". . . . no sign of a nest." Four eggs were laid. These are but a few of the published records of the ground nesting of Robins, but they furnish a representative sample.

Jones (1891) states that Mr. Jacobs found nests on ledges of rocks. Burleigh (1927) mentions a nest imbedded in the top of the upturned roots of a large tree at the side of the road.

Robins occasionally nest in holes in trees and in bird houses. Andros (1884) presents an account of a loosely built nest in a large knot hole in an oak. Stone (1894) reports a nest built on the floor of an old Flicker cavity where the top of the tree had broken off above floor of the hollow. Fish (1916) records a nest placed in an open slit between two arms of a stump, 3½ feet above the ground. Stewart (1931) writes of a nest in a woodpeecker cavity, 20 feet up in a tree. The nest was built in the usual manner. He reports another Robin nest in one of the four compartments of a Martin house. Both notes are from Ohio. Trafton (1907) report Robins nesting within covered-over bird houses.

The multitude of man-made structures offer Robins some very satisfactory nesting sites. It is interesting to note that most of these artificial sites have been available to these birds for a comparatively short period of time. In some parts of the west where Robins place their nests on houses, the settlers were absent a hundred years ago. The nesting habits of these birds must have changed with rather remarkable rapidity. The following are some of the man-made sites used by this species.

Kennedy (1915) remarks on the fact that houses are frequently used in the treeless parts of the west. Smith (1920) reports a nest on the hub of a wagon; another one on a smoke pipe; one inside a blacksmith's shop only 8 feet from the anvil where the smith hammered and the sparks flew. A brood was raised here. In another strange case a Robin built a nest on a tank car

in a switch yard. This nest was moved four times to other tank cars, yet the parents remained with the nest, and finally it was placed on a shelf nailed to a stake in the yard. Here the birds raised a brood. Evermann (1889) reports that in Caroll Co., Indiana, Robins often nest on fence rails. Perkins (1921) reports a fire escape which had eight nests on it, one to a step. Miller (1930) writes of a pair which raised two broods in a nest which entirely stopped up a gutter and caused it to run over during heavy rains.

There is a photograph of a Robin's nest on a chandelier in Bird-Lore, vol. 24, p. 215. A nest was built on a chandelier hanging in the entrance to the Cornell Library in 1938. The birds had free access to the nest from two sides. Hundreds of people passed ten feet below it each day, yet a brood was raised.

Severson (1921) describes a nest located at the intersection of three cables of a trolley line. Trolleys passed every few minutes only inches beneath the nest, yet a brood was raised. Tess (1926) states that a Robin built its nest on a gate and so swang back and forth often each day. Eggs were laid and incubated up almost to the hatching point before a mishap befell the nest. Adair (1920) writes of a nest on the arm of a signal which swang out over a railroad 50 times daily. Often the trainman's hands were inches from the nest. A brood was raised. There is a photograph of the nest. Jones, A. H. (1930) presents a photograph and brief account of a nest in the lap of a brooding marble figure of sorrow over a grave. The highest nest of which I have a record is one that Eaton (1914) reports. It was placed 80 feet up on a beam of a water tower.

RELATION OF THE NEST SITE TO THE REST OF THE TERRITORY

There is no constant relationship between the limits of the territory and the location of the nest. As often as not the nest is out in what appears to be a corner of a territory. In one case, two nests occupied at the same time, were only 18 feet apart. Both of these pairs must have had their nests near the border between the adjoining territories.

CONSTRUCTION OF THE NEST

RELATIONSHIP OF THE SEXES IN NEST BUILDING

My observations fail to show a single instance in which a bird known to be a male took part in the building of a nest. Yet there are a number of published accounts of male Robins assisting in building the nest. Forbush (1929) writes that the nest is built chiefly or entirely by the female. Samson (1923) reports that both parents took part in building a nest. However, while the male carried material for building, the female did most of the arranging of the materials—particularly toward the close of the building period. Jordan (1901) states that a male helped his mate build for part of the first day, but his efforts ceased then.

The case of an unusually industrious male is reported by Kelly (1913). He watched a pair building for an unbroken period of eleven hours. During this time the male made 86 visits to the nest with material and the female made 108. The female brought the larger loads. The male was observed to

drop his load of material if his mate was busy shaping the nest and kept him waiting. Most of the material was gathered 150 yards from the nest. The male journeyed 14 miles in his travels to and from the nest; the female flew 18 miles. On the following day an egg was laid in the nest, which had been completed in one day of hard work. While the male played an important part in the carrying of materials to the nest, the actual shaping of the nest was done entirely by the female.

PROCESS OF NEST BUILDING AND THE MATERIALS USED

The building of a Robin's nest may conveniently be divided into three stages. The foundation is the first step. This part of the structure includes the entire outer wall of the nest. Usually this outer shell of the nest is composed largely of long, coarse, dead grass stems, but green grass is used at times. Sometimes there are twigs in this part of the nest. Paper, usually white, dead weed stems, string—both white and brown, feathers, and rootlets are frequently used. A number of materials show up occasionally in the nest, perhaps through design, or they may have adhered to some more usual material. In one nest I examined there was a length of two or three inches of cast-off snake skin. Moss is used rarely, and at times a dead leaf will be included in the nest.

Now and then a Robin will depart from the usual choice of nest materials and build a bizarre structure. In May, 1939, Mr. J. S. Y. Hoyt brought in to me an odd nest which was built in a low conifer on the farm of Mr. Lane, at Sapsucker Woods, near Ithaca. The foundation of this nest was a great mass of white feathers. The feathers often blew out of the nest and were on the ground all about the nest and adhering to all parts of the bush. Eggs were laid in this nest but the nest was broken up. This pair built another nest nearby and again they had ill luck and the eggs were destroyed, perhaps due to the use again of many feathers which advertised the presence of the nest. A third nest again contained many feathers.

Allen (1930) shows a picture of a nest which had a framework composed largely of narrow ribbon-like shreds or streamers of white paper. Forbush (1929) writes of a nest composed only of cotton and mud. It stuck out like a sore thumb in the tree where it was placed. A Mrs. Leach reports (anonymous, 1917) that she induced a pair of Western Robins to incorporate gaudily colored cloth in their nest by attaching bits of string, which the Robins wanted, to the cloth. Parsons (1906) records a nest of Robins adorned with badges worn by convention delegates. Bits of lace, feathers, and colored string were also used by this pair of birds. Scott (1879) states that in Colorado all the nests he found were curiously built of sage-brush. Forbush (1929) relates an experiment where a Robin which was building a nest was given strings of all colors. The bird used only white string.

The second step in building a nest is the forming of a mud layer. Strictly speaking the mud layer is not a separate stage in the building of a nest as it is put in place at the same time the outer walls are completed. The grass of the outer frame is meshed in the hardened finished mud wall.

The female carries the mud to the nest in its bill as well as on it. Usually the nearest source of mud or clay is used, but in dry seasons this may be at some distance from the nest. A banded female was seen gathering mud a quarter of a mile from her nest at Ithaca, N. Y. At times Robins will make mud for themselves if none is available. Forbush (1929) writes of one that entered some water, wet her feathers, and then shook this water off in the dust of the road. Another filled her bill with dry earth and then dipped her bill into a bird bath. He states that during dry seasons, nest building birds will take mud or clay from shallow trays placed where the birds will find them. Rohrback (1916) states that the castings of worms are the most often used source of mud.

During April these birds will often stop building for a day or two after completing the mud layer. Forbush (1929) believes that this is to allow the mud to dry. If for some reason the birds are in a hurry to complete their nest there will be no pause at this point.

As soon as the female begins carrying mud or clay to the nest she ceases to stand beside the nest when she is building. Then she nearly always works from within the nest. When she arrives at the nest she drops the mud into the floor of the nest in the form of rough gummy pellets. She settles on these pellets and kneads them into the foundation by rotating round and round in the hollow of the nest. Some writers state that the legs and feet are used also in this process, but I feel that the part they play is a secondary one. Often when the female is engaged in this process she becomes coated over the lower breast and belly with mud. A dark band is formed across the breast where the mud from the rim of the nest has dried on her feathers. The mud used about Ithaca is of brownish gray color.

In rare cases this mud layer will not be put into a nest. Nests without mud are recorded by Osgood (1906), Forbush (1929) and Johnson (1935). The latter nest was found in North Dakota in the drouth of 1934 when no mud was available. Mitchell (1894) writes of a nest wherein manure was substituted for mud.

McClanahan (MS 1935) carefully separated the mud from the rest of the nest material. This was accomplished by thorough washings. After completely drying the nest materials they were weighed. The weights are given below:

Mud	123.3 grams
Weeds, grass, etc.	129.35 grams
Total weight	252.65 grams

The final step in building is the lining. In lining the nest grass blades are by far the favorite material, although occasionally a few grass stems or twigs will be used. Forbush (1929) states that any fibrous material such as seaweed, cloth, string, yarn, cotton or paper may be used. Most of the grass used is dead but now and then a green blade or two is used. Jones (1891) writes of horsehair being used to line a nest.

The material may be gathered at a distance 150 yards from the nest or it

may be picked up within 25 feet of the nest. The female gathers the grass blades for lining in large gobs, as many as 25 or more at a time. Often she will have a mass of grass blades as large as her head. At such times she may experience some difficulty in carrying so cumbersome a load. On reaching the nest the female hops to the brim and dumps the grass unceremoniously into the hollow and hops in on top of it. She then settles down on the material and squirms round and round, smoothing out the blades. Now and then she reaches down with her bill to properly locate some unruly bit of lining.

TIME REQUIRED TO BUILD A NEST

The time spent in arranging the nest material is extremely short. The female flies to the nest, arranges the material and flies off again for another load in a period of a minute or two. On April 16, 1938, I watched a female lining a nest. At 2:00 P.M. the nest had just the barest beginning of a lining, yet by 5:00 P.M. the nest appeared to be fully lined.

A nest may be entirely constructed in a single day, as reported by Kelly (1913). The nests built during the second and third nestings are usually constructed with greater speed than the first nests. Two or three days is about the average amount of time needed for these later nestings. The more slowly built eaarly nests are usually completed after 5 or 6 days. Some of these early nests are started when the weather is uncertain. In such cases the building operations may be suspended in the event of a cold snap until the return of favorable conditions. The nest often will not be completed for ten days. Knight (1908) writes of a nest that was not completed for twenty days.

SHAPE AND MEASUREMENTS OF THE NEST

The shape of a Robin nest is roughly that of a bowl. Usually it is greater in breadth than height, although the reverse is sometimes the case. The shape of the nest is governed to a large extent by the site chosen. A nest placed on a ledge against a wall will have one flat side and the base will be flat. The nests having the greatest height are those placed in upright forks, a site not often used by Robins.

The measurements of nests given in table 3 are indicative of the range of variation. The first three numbers refer to individual nests found at Ithaca, while the numbers 4 to 6 refer to groups of nests reported on by Jones (1891). Numbers 4 and 5 are sets of measurements taken from Pennsylvania nests. Under number 6 are given figures for some Iowa nests. Numbers 4 and 6 show the range of variation within the group of nests studied, while number 5 gives an average measurement for the nests studied.

TABLE 3.—Measurements in millimeters of Robin nests.

No. of nest or Group of nests	Outside diameter	Outside height	Inside diameter	Inside depth
1	200	200	90	55
2	150	90	95	55
3	130	110	80	65
4	125–150	75–100	87.5–100	50–62.5
5	87.5	100	69	62.5
6	125–162.5	75–106	87.5–106	50–60

The thickness of the wall about half way down from the rim to the base is about 20 mm. It shows little variation.

WEIGHT OF THE NEST

Nest weights vary greatly with change in water content. The weights on the first three nests in table 3 were taken after the nests had been in a cabinet for three months or more and were thoroughly dried out. Nest no. 1, weighed 201 grams; no. 2, 179 gms. and no. 3, 186 gms. The nests grouped under no. 4, weighed from 142 to 227 gms. and one of the nests grouped under no. 5 weighed a pound or 454 grams. This last nest was probably a fresh nest and was moist when it was weighed.

RE-USE OF THE NEST AND NEST SITE

The Robins will often build another nest in the same site if its nest is removed. This happened twice during my studies at Ithaca. Nest no. 41 was collected and the female banded on the evening of May 2, 1937. This same female built another nest in the same site. Nest no. 42 was collected along with the four eggs and the female bird on May 7, 1937. A new nest was built in the identical site, presumably by a new mate of the male whose mate had been killed, and it held one egg only 12 days later.

At times a pair will use one nest in which to raise more than one brood during a season. Nest no. 11 was located on the elbow of a drain-pipe, and two broods were raised in it during 1937. Nest no. 7 was placed partly on a transformer and partly on the crossbar of a telephone pole and used successfully to raise two broods. Wright (1918) gives the history of a pair which in 1916 raised two broods in a nest in a woodbine against his cottage. In 1917 a pair of Robins thought to be the same one, built a nest nearby against the side of the cottage. Two broods were raised in this nest. Just after the second brood left the nest it was torn down. This pair then moved to the 1916 nest to raise their third brood. Allen (1928) comments on the fact that nests in trees are rarely used twice during a season. Nests on houses are usually better anchored than those placed in trees and are safer from predators, excepting perhaps cats. When used twice in a season the nest may or may not be relined, but I have no evidence of a new nest being built on an old nest of the same year. In the early part of the nesting season, however, a complete new nest is often built on an old nest of a preceding year.

Some pairs of Robins become so attached to a particular site that they return to it year after year. Each year that the nest is used a new nest is built on the one of the year before. A huge nest was brought to me in 1938 that consisted of seven complete nests built one on top of the other. It had been removed from a beam in a barn. Probably the nest had been used for seven different nesting seasons. Almost certainly more than one pair of Robins had used this nest over its long history, for few, if any, Robins live for seven years. These multiple nests are not apparently very rare as I have records for four that were combines of three or more nests. In all cases these nests were

placed on some man-made site and not in trees. However, Dr. A. A. Allen told me of a nest of five or six stories low in a wild apple near Varna, N. Y., in 1937 or 1938.

USE OF THE NESTS OF OTHER SPECIES

It is unusual for the Robin to use the nests of other species of animals. Sometimes the use of the nests of other species does not involve an intimate relationship as is true in the following cases. Hough (1906) presents a picture of a Robin nest built on top of a Baltimore Oriole nest of the last year. Holt (1927) records an instance of a Robin's nest being placed on top of a Hornet's nest of the preceding year. Frost (1931) writes of a Robin's nest built on top of an old House Wren's nest that was on a transom over a door.

At times Robins will use the nest of some other species at a time when the owners are also using it. Andros (1884) writes of flushing a Robin from a Cedar Waxwing nest in which there were four eggs of the Waxwing and one of the Robin. A Cedar Waxwing was on a limb near the nest. The account stops here as the eggs were collected.

A somewhat similar instance came under my observation at Ithaca during 1938. In this strange case a Robin laid one egg in a nest which held two eggs of the Blue Jay. Arnold (MS 1938) gives an account of this nest in his study of the life history of the Northern Blue Jay.

The Blue Jay was seen building the nest and on April 15 it was flushed from the nearly completed structure. The nest (no. 160) was 30 feet up in a 50 foot white Pine and 15 feet out from the trunk. The Blue Jay laid an egg on the 23rd of April and another on the 24th. On the latter date the Jay was flushed from the nest. The nest was next visited on the 26th when Dr. Arnold was greatly surprised to flush a Robin from the nest. There were two eggs of the Jay and one of the Robin then in the nest. No jays were about the nest at this time, nor were any seen later. The nest was next visited on May 11, when it held one young Robin and one egg of the Blue Jay. When the nest was visited on the 14th it held only the young Robin. A careful search over the ground beneath the nest disclosed no remains of the eggs of either species. The young Robin left the nest successfully.

A close examination of the nest shows it to have a most anomalous construction. The bottom of the nest is like that of a Robin, being largely of grass and mud. There are grooves in the mud of the outer floor of the nest where the nest was saddled on the branches. The outside of the upper half of the nest is of twigs and closely resembles the nest of a Blue Jay. The lining is double, a coarse lining of rootlets on the inside of the cup of mud, which is typical of the material used by the Jay, and on top of the rootlets is a grass lining like that of the usual Robin nest. In some manner the Robin was able to put in a lining under the eggs as there was no grass in the lining of the nest when it was examined on April 24.

In interpreting this episode Arnold thought that the Blue Jay had built its nest on a nest of last year, or earlier, of the Robin. He believed that the Robin had reclaimed its old territory from the Jay, or as an alternative, he

suggested the possibility that the Jay abandoned its nest after he climbed to it on April 24, and that the Robin then took over the nest. In as much as there is no material suggestive of the lining of a Robin's nest beneath the rootlet lining of the Jay, and further because the rootlets are actually imbedded into the mud, I feel that the Jays probably drove the Robins from the nest just before they put the lining in place. The Jays then proceeded to line the nest with rootlets and added twigs to the outside of the nest. After the Jay's nest had been disturbed through being climbed to on two successive days, the parents deserted the nest and the two eggs it contained. At this point it seems likely that the Robins had an accident befall their nest which was destroyed with all but the final egg of their clutch. The female Robin then visited her earlier nest from which the Jays had driven her and finding it undefended, reclaimed it and deposited the final egg of her clutch in it.

It seems unlikely that a pair of Blue Jays could have been driven from their nest and eggs by a pair of lighter, less pugnacious Robins.

USE OF ROBIN NESTS BY OTHER SPECIES

The Robin at times shows a remarkable tolerance of other species about its nest. Under the section dealing with territory is an account of a Robin and a Mourning Dove using a nest at the same time, and also a record of a pair of Western Robins and House Finches both having young in the same nest. In these instances both species attended the nest.

Center (1885) reports three young House Wrens in a Robin's nest which also contained three young Robins. Two of the young Wrens were raised by the Robins and they successfully left the nest. No mention is made of the parent House Wrens, it therefore appears that in this case the House Wren behaved as a nest parasite.

Davison (1887) records a Robin nest that had a most unusual history. It had been possessed by a Yellow-billed Cuckoo before the Robin had lined it and the Cuckoo had filled it with rootlets. In this condition the Robin had laid one egg in the nest and the Cuckoo two. The Cuckoo began to incubate. Soon a Mourning Dove joined the Cuckoo on the nest and it laid two eggs. When the above writer collected the set, both the Mourning Dove and the Cuckoo were on the nest. The eggs of the Robin and the Cuckoo were slightly incubated and those of the Dove were fresh.

Widman (1882) states that he found the eggs of a Yellow-billed Cuckoo in a Robin nest. Mitchell (1823) mentions that a Solitary Sandpiper used an old Robin nest in which to lay her eggs. Gray (1897) reported a case where a Mourning Dove drove a Robin from the latter's nest. Nice (1921) writes of a Mourning Dove using a Robin nest. At Ithaca in 1938 I found a Mourning Dove incubating two eggs placed in the hollow of a recently abandoned Robin nest which the Doves had relined. Murie (1933) writes of a pair of Chickadees which built their nest in an old Robin nest. The report is from Wyoming. Burleigh (1931) reports an English Sparrow putting a lining into a Robin's nest and raising young in it. No arch was put over the nest. Bassett

(1923) reports that a Mountain Chickadee spent seven successive nights in a Western Robin's nest.

DUPLICATE NESTS

Then occasionally a Robin has what seems like a mania for nest building. One season a Robin built three nests over my cottage door and as many as ten nests or partial nests have been built by one bird in a season on some beam of an outbuilding. [Forbush (1929)].

Bruen (1905) relates of one bird that built five nests within a few feet. She laid eggs in two of them. During incubation she sat on one nest and then the other, yet she finally hatched two eeggs in one of the nests. Wetherbee (1930) gives an account of a pair of Robins that built five nests on a beam under a rabbit house. Nests 1 and 2 both held two eggs, 3 was not finished but held one egg. Nests 4 and 5 were only half built. Another egg was near the nests on the ground.

It seems likely that these instances of a bird building more than one nest represent cases where the instinct for nest building is faulty. In both of the above reports more than the usual number of eggs (three or four) was laid. Perhaps more than one female was concerned in the reports.

NEST PARASITISM

Friedmann (1929) has the following to say of the relationship between the Cowbird and the Robin:

Probably an uncommon victim. It is hard to state definitely the extent to which this bird is affected by the Cowbird because the parasite eggs are practically always thrown out. Half a dozen or more records from New York, Connecticut, Iowa, North Dakota, and Alberta have come to my notice.

At Ithaca I watched a Cowbird lay an egg in a Robin's nest. (See under discussion of Egg Laying) The Robin drove the Cowbird off the nest just as she finished laying the egg. To quote from my field notes—".... one of the old Robins came back to the nest after chasing the Cowbird some distance, looked in, gave two syllables of its distress call, and then drove its bill through the Cowbird egg and with a jerk of its head threw the egg out.... The Robin gave a few more syllables of its distress call but not as loud as before and then settled on the nest."

Experiments were made to see whether the Robin detected the strange eggs from her own by differences in color or size or both and it was found that color was the chief factor. Chipping Sparrow eggs, which are even smaller than Cowbird's, were accepted by the Robin while larger eggs, more nearly approximating in size those of its own, but not as similar in color, were rejected.

Although Cowbird eggs are not tolerated by Robins on one occasion I put two very young Cowbirds in a Robin's nest which contained only eggs at the time. The Robins stopped incubating their own eggs and took care of and reared the young Cowbirds. On one occasion I chanced to pass the nest when the Cowbirds were about seven days old and found that about two inches of the tail of a very small garter snake was protruding from the bill of one of the Cowbirds. The bird finally swallowed and digested the snake!

The Rev. J. Walton (Ool. 1879, p. 78), records seeing a female Robin sitting on a nest which proved to contain three eggs of the Robin and one of the Cowbird.

Jensen (1918) records a nest parasitized in North Dakota. Perkins (1923) mentions in passing the nest of a Robin which contained only a Cowbird's egg. Friedmann (1934) reports a nest parasitized in Missouri, and another in

Maryland which held two eggs of the Cowbird. Blincoe (1935) wrote an account of witnessing a female Cowbird drive her mandibles deeply into a Robin egg and carry it to the ground.

To determine the reaction of Robins to the eggs of other species, I placed some foreign eggs in Robins' nests. Two Cowbird eggs, placed in different nests, were both removed, but no observations were secured as to how they were taken from the nest. A Starling egg, which had a large white piece of tape on it, was removed from a Robin nest where I placed it. In another nest I placed both a Cowbird's egg and a Robin egg that was old and had a dead embryo in it. Again the Cowbird egg disappeared from the nest, but the strange Robin egg was retained. On June 3, 1938, a pipped egg of a Catbird was transferred to a Robin nest which held pipped eggs. When visited on June 5 there was no sign of a Catbird egg or young one.

Some instances appear in ornithological literature of the nests of Robins being parasitized by species other than the Cowbird. The report by Center (1885) where three young House Wrens were raised by a pair of Robins in addition to their own brood, seems a case of nest parasitism. Perhaps some human placed the Wren eggs or young in the Robin's nest. Rohrback (1913) writes of an instance of a female Robin being driven from her nest by English Sparrows, one of which laid an egg in the Robin's nest.

There are some observations which show that at times the Robin parasitizes the nests of other species. Munro (1936) records finding a freshly laid Robin's egg in a Ring-billed Gull's nest in Alberta. The gulls were nesting on an island which had no Robins present on it. Davison (1887) found a nest of the Phoebe in which a Robin's egg was nearly imbedded. Herman (1923) writes of a nest on a brush pile that was built on the outside by a Brown Thrasher, lined by a Robin, and contained 4 eggs of the Thrasher and 1 of the Robin. The Thrashers were the only birds at the nest. Bartram (1926) reports a nest of Purple Grackles in Bucks Co., Pa., which contained two of their eggs and one of the Robin. The Grackles did not throw out the egg for a few days, but it was destroyed before it hatched.

Forbush (1929) states that Robins sometimes lay their eggs in nests of other species and he believes that these cases are the result of the Robin's nest having been destroyed during egg laying, causing the female to lay in another bird's nest as an emergency measure.

There are no examples of the young of a Robin hatched in the nest of another species having been raised by the parasitized birds.

Eggs

NUMBER OF THE EGGS

The number of eggs laid by a Robin is usually three or four. However, complete sets may consist of a single egg as was the case with the pair of Robins which used the same nest as a pair of Blue Jays. (Reported under the section on the use of the nests of other species). In cases where only one egg is found in the nest it is highly probable that some of the eggs of the clutch were destroyed or laid while the bird was away from the nest. Sets of only

two eggs are not uncommon, but in such cases it is probable that one or two eggs have been destroyed in some manner. The number of eggs most often laid in the Ithaca region is three, if the entire nesting season is considered. During 1937 and 1938 the number of eggs laid was checked in 127 nests and it was found that 65 held three eggs and 55 held four eggs. After May 15, or as soon as the earlier second sets are laid, three eggs are more commonly laid than four. However, during the first laying period there are more sets of four than three.

Sets of five eggs are uncommon. Of more than 130 complete sets observed at Ithaca only two were of five eggs. Mousley (1916) examined 68 nests in Quebec and not a single one held five or more eggs. Six eggs are sometimes laid by a single female, but such large sets are rare. At Macwahawk, Me., on June 9, 1934, the writer found a set of six eggs which were uniform in size shape, and incubation. Forbush (1929) states that six eggs are rarely laid. Ingersoll (1913) records a nest containing six eggs in the Sierra Nevada at Cisco, Placer Co., Cal., in June, 1912. Eaton (1914) writes of a set of seven eggs which he thought was laid by one female. At Ithaca two sets of seven (or perhaps eight) eggs were found, but both were known to have been laid by two females which used the same nest for two layings. Nests containing eight eggs have been found on a number of occasions (see pp. 536-7 for account) but it seems highly probable that these large sets are the product of two females.

Table 4 gives the frequency with which various numbers of eggs were laid in complete clutches at Ithaca. The two sets of seven eggs mentioned above are not included.

TABLE 4.—Number of eggs laid in complete clutches of eggs at Ithaca, N.Y.

Number of eggs in clutch	1937	1938	Total
1 egg	0	1	1
2 eggs	2	3	5
3 eggs	30	35	65
4 eggs	28	27	55
5 eggs	0	1	1
6 eggs	0	0	0
Total	60	67	127

One pair of birds will often lay more than one set of eggs in a season. The first set laid nearly always contains as many eggs as subsequent sets, and often more. If three broods are raised the third set is nearly always of only three eggs. One pair laid 4 eggs in its first nest, 2 eggs in its second, and 3 in its third. In the second nesting I believe that some mishap befell an egg or two.

The banded female which built nest no. 10 in 1937 laid 4 eggs, while in 1938 and 1939 she laid five eggs. Banded female no. A337142 laid four eggs in 1937 and 1938. Banded female no. 37-319610 laid three eggs in both 1937 and 1938. In none of these instances did a female lay fewer eggs during the second year than the first, and in one case a female laid more eggs on her first laying for the second and third years than for the first.

Attempts to stimulate female Robins to lay more eggs than are usually present in a clutch proved fruitless. The third egg was removed from nest no. 5

soon after it was laid, following this the female abandoned the nest. The third egg laid in nest no. 6 was collected, and the following day the fourth egg was collected. The female laid no more eggs and succeeded in raising two young from her first two eggs. One egg was taken from nest no. 38 and one left in the nest on May 5, 1937. On the following day the third egg laid was collected. No more eggs were laid, but the single egg remaining in the nest was hatched, and the young one was raised.

I do not know why Robins cannot be stimuated to lay more than the average number of eggs. I removed the ovary from a female that had just laid four eggs and found that in the ovary was a yolk a little less than half the diameter of a yolk before it breaks free of the ovary. This yolk may have been even larger as it was not turgid and probably it was waning in size. In the ovary of a female that was apparently about to ovulate were found yolks of the following diameters: 13 mm., 10 mm., 7 mm., 4 mm., and three other yolks were over 2 mm. in size. More yolks are enlarged than are freed to form mature eggs.

COLOR OF THE EGGS

The color of the eggs of a Robin has become a standard of comparison. Actually the blue of a Robin egg has a great deal of green in it. The color most nearly approximating that of the deeper colored Robin eggs is Nile Blue.* In matching the lighter colored eggs I found them to be Deep Bluish Glaucous. These determinations were made from shells collected over a year prior to the matching, but they had not been exposed to light.

On very rare occasions Robin eggs are spotted with brown. Fisher (1878) reports such a set taken at Lake George, N. Y. An egg which he examined was marked very much like that of a Scarlet Tanager, the greater number of spots being at the larger end, the rest of it being sparingly spotted. Lovejoy (1884) records a set of four eggs having spots of light, pale brown, some of the largest the size of a pin's head. Tracy (1884) reports a set of four spotted eggs.

White eggs seem to be as rare as spotted eggs. In these cases the pigment glands which usually deposit blue coloring matter over the eggs do not function. Brooks (1933) and Loveridge (1939) report a nest found on June 11, 1924, at Arlington Heights, Mass., that contained eight eggs, six of which were white and two were normal in color. Hersey (1933) reports a nest found on May 13, 1931, at Norton, Mass., which held five white eggs.

SIZE OF THE EGGS

To determine the size of the average Eastern Robin egg in the Ithaca region thirty eggs were measured. *All measurements are in millimeters.* The average length was 28.44 and the average width was 20.71. The greatest length was 31.9 (x 22.7) and the shortest was 24.9 (x 20.0). The greatest width was 22.7 (x 31.9) and the shortest width was 18.8 (x 25.9).

* Where colors are capitalized they are taken from Ridgway (1912).

Baird, Brewer and Ridgway (1905) give the length as being from 31.7 to 28.4 and the width as 22.3 to 19.0 Forbush (1929) gives the following measurements: 32.0 to 26.6 x 21.6 to 19.8 Reed (1904) gives the average as 29.2 x 20.3. Roberts, T. S. (1932) gives the average as 29.2 x 19.8. Chapman (1934) gives the average as 29.0 x 20.3.

A decidedly runt egg was found in a nest (no. 214) on May 28, 1938. It measured only 23.5 x 18.0, and was not included among the thirty normal eggs measured to determine the average size for this region. Ray (1913) gives the measurements of a runt found in the Lake Tahoe region, Cal., as 24.6 x 19.0. The largest egg of a set is most often the first one laid, although any egg from the first to the last may be the largest. Mousley (1917) collected three sets of eggs, one after another, from a pair of Robins and reported that the size of the eggs making up the sets grew consecutively smaller.

WEIGHT OF THE EGGS

Sixty eggs weighed at Ithaca averaged 6.26 grams. Forty-five of these eggs were fresh, and of the remaining fifteen none were over half-incubated. The heaviest eggs were two from nest no. 10 both of which weighed 8.4 grams. The lightest normal egg weighed 4.6 grams. A runt egg from nest no. 214 weighed only 3.75 grams.

Hamilton (1935) gives the average weight of twelve freshly laid eggs as 6.58 grams. His observations led him to believe that during incubation as much as 25% of the original weight of the egg was lost. Three eggs which I weighed when they were fresh totaled 20.5 grams and at hatching they weighed 18.0 grams. In this case the loss was 2.5 grams or 12% of the original weight. Two other sets were used as checks and they both showed a loss of about 11%. As accurately as could be determined the rate at which the loss took place was about the same throughout the period of incubation, however the data are not exact enough to serve as more than indicative of the actual rate.

Bergtold (1929) gives two weights for Robin eggs as 7.31 and 4.66 grams. He weighed the empty shell of the larger of these two eggs and found its weights to be .38 of a gram. He gives the specific gravity of the above eggs at 1.027 and 1.024 respectively. Four empty egg shells from nest no. 10 weighed 1.4 grams or .35 of a gram apiece. These were exceptionally large eggs.

SHAPE OF THE EGGS

The shapes of Robin eggs differ little from those of the chicken. They are ovate, or typical shaped eggs.

TEXTURE OF THE EGG SHELLS

Most Robin eggs have shells that are smooth and non-granular. Now and then an egg is laid which has a rough granular texture. Such eggs seem to be characteristic of certain female Robins. The female of nest no. 16 and no. 58 laid eggs that were usually quite granular. Some of her eggs were much more granular than others. So smooth is the usual Robin egg that it has a distinct shine or gloss.

EGGS THAT DO NOT HATCH

It is usually a difficult matter to determine exactly why an egg does not hatch. It can safely be stated, however, that in most cases where Robin eggs do not hatch the embryo is not well developed. Thus it seems that the most frequent reason that eggs do not hatch is that they are infertile. Few embryos die after having started in their development.

A study was made of 259 eggs which did not all hatch although they were incubated long enough so that they should have. Of these 259 eggs 18, or 7%, did not hatch.

TIME OF DAY AT WHICH EGGS ARE LAID

Robins usually lay their eggs about 10:00 A. M. At Ithaca the earliest laying of an egg was between 7:40 and 9:25 A. M. The latest was between 10:15 A. M. and 1:35 P. M. Table 5 gives the times at which eggs were laid in nests at Ithaca.

TABLE 5.—Time at which Robin eggs were laid at Ithaca, N. Y.

Nest No.	Egg No.	Times between which eggs were laid
1	II	7:40 A.M. & 1:30 P.M.
	III	7:25 A.M. & 12:30 P.M.
	IV	7:35 A.M. & 10:10 A.M.
2	IV	10:07 A.M. & 1:40 P.M.
6	IV	8:15 A.M. & 2:35 P.M.
10	IV	7:00 A.M. & 10:40 A.M
13	II	6:45 A.M. & 10:50 A.M.
	IV	8:00 A.M. & 12:00 P.M.
25	III	9:20 A.M. & 11:15 A.M.
	IV	10:15 A.M. & 1:35 P.M.
61	II	7:40 A.M. & 9:25 A.M.

Murray (1930) gives the time for the laying of two eggs. One was laid between 11:00 A. M. and 12:30 P. M., the other was laid between 12:30 P. M. and 2:00 P. M. Both of these are later laying than most of those that came under my observation. Dice (1918) reports the laying of an egg between 8:30 and 9:15 A. M. Another egg was laid between 9:30 and 10:30 A. M. The first egg was laid on May 4, 1908, the second on the following day. The observations were made in Washington and refer to the Western Robin. Howe (1918) writes from Massachusetts that eggs are laid between 11:00 P. M. and 4:00 A. M. This is at variance to the above data.

INTERVAL BETWEEN THE LAYING OF THE EGGS

In all cases in which I checked the interval between the laying of eggs it was always about 24 hours. Hodgson (1919), however, reports a female which laid three eggs, then waited two or three days to lay her fourth egg. The young from the final egg starved to death because the larger young secured almost all of the food. In cases where such a gap occurs between the laying of two eggs, it is likely that on the day in which no egg was laid in the nest an egg was dropped by the female outside of the nest.

INTERVAL OF TIME BETWEEN SETS OF EGGS WHEN THE NEST IS BROKEN UP

When the nest of the Robin is broken up the female will usually build a

new nest and deposit another set of eggs. A female may build a nest and lay a complete set in 9 or 10 days in such an emergency. In some cases the time is much longer, as much as sixteen days or more. Mousley (1917) collected three sets, one after another, from a pair of Robins. Both the second and third sets were completed ten days after the preceding set had been collcted. As a rule a fresh set of eggs that has been destroyed will be replaced sooner than a set of eggs which has been partly incubated before being broken up.

INCUBATION OF THE EGGS

DURATION OF INCUBATION

At Ithaca the incubation period is from 12 to 14 days in length. The period is here taken to be the length of time that it takes a bird to hatch an egg. It starts when the female begins to sit on her eggs without interruption, and ends when the young Robin breaks free of the egg shell. The beginning of incubation is often difficult to determine. Some Robins begin to incubate as soon as the first egg is laid, others do not start until the last egg is deposited. The nearest to a fool-proof method of determining the incubation period is to mark the last egg of a clutch as it is laid and then check the time at which it hatches. As incubation seems always to start with the laying of the last egg, the hatching of this egg gives a definite check of the incubation period.

The incubation period of seventeen eggs was carefully checked. Six of these eggs hatched in twelve days, eight in thirteen days and three in fourteen days. It was found that there was sometimes a variation of as much as a day in the incubation period of different eggs in the same nest.

Table 6 gives a number of incubation periods that have been published.

ACTIONS OF THE PARENTS DURING INCUBATION

At Ithaca I have never observed a bird known to be a male to incubate. Numerous checks were made on nests where one, or both, of the parents were banded to determine which sex incubated. Nest no. 110 was checked on 13 occasions and each time the banded female flushed from the nest. Nest no. 114 was checked 10 times and only the female incubated. Other checks revealed only female birds incubating. The times at which these checks were made were scattered throughout the daylight hours.

TABLE 6.—Length of incubation period of Robin.

Incubation Period	Authority
11–12 days	Herrick; from Burns (1921)
11–13 days	Eaton (1914)
11–14 days	Forbush (1929)
12 days	Redfield; from Burns (1921)
	Stanford; from Burns (1921)
12–13 days	Tyler; from Burns (1921)
12–14 days	Howe (1898)
13 days	Judson; from Burns (1921)
	DuBois (1920)
14 days	Saunders (1914)
	Samson (1923)
	Murray (1930)
	Roberts, T. S. (1932)
	McClanahan (MS, 1935)

Allen (1928) states that the male does not incubate. Jordan (1901) also states that the female does the incubating, but writes that on the tenth day of incubation, at a nest under observation, the male was witnessed to stand on the edge of the nest while the female went in search of food.

On May 13, 1939, a male was seen singing from the rim of a nest which held three eggs and one young which was just hatched. He did not incubate the eggs.

Howe (1898) reports that the male may incubate but not for more than three minutes.

Forbush (1929) writes on this subject as follows:

> Usually while the female is building her nest and incubating her eggs the male stands guard, feeding her occasionally. Often when the female leaves the nest the male comes and keeps watch nearby if not on the nest. Some males, however, insist on doing their share of the incubating and brooding, and some probably would more if the females would allow them. Mrs. Elizabeth L. Burbank of Sandwich, Massachusetts, says that a male Robin has acted in a peculiar manner for two seasons. While the female sits closely on her nest he often repairs to a certain spot in the grass where he can look up at his mate in the nest, and there sits as if on a nest, acting like an incubating bird, fluffing out his feathers, rising up and seeming to turn eggs at times; and this happens day after day. Doubtless this bird has been mated with another female in the past and had been accustomed to relieve her on the nest.

McClanahan (MS, 1935) studied a nest in detail during the summer of 1935 at the University of Michigan Biological Station near Cheboygan, Mich. He reports that incubation was carried on mainly by the female, the male, however, was seen to relieve her on several occasions and he also brought food to the sitting bird. The sitting bird faced in two directions, northeast or southeast, but it entered the nest from all directions. Whenever the bird left it was only for a short time, averaging 5 minutes, although it stayed away for 13 minutes on one occasion. The eggs were covered about 50 minutes of every hour. While the female was on the nest, the male often sang. He showed no tendency to select any certain tree; however, he never sang in the nest tree. Singing stopped entirely a day or so before the eggs hatched. At night the female covered the eggs and the male could not be found. He must have been at some distance from the nest since he did not respond to the alarm notes of the female. During the day he was always in hearing distance of her distress calls to which he responded readily.

My observations on the length of time that the female stays away from the nest in search of food tally very closely with those of Mr. McClanahan. The female may sit on the nest without a break as long at forty minutes. Her feeding radius is usually not more than 200 feet from the nest.

At times the male sings throughout the incubation period as on May 13, 1939, a male sang from the rim of a nest in a spruce tree which contained one young just hatched and three eggs. Males may sing when there are large young in the nest. While the male is often within hearing distance of the nest I have on a number of occasions visited nests at which the female scolded loudly but failed to bring her mate to her assistance. As reported by Mr. McClanahan my findings also show that the male is not near the nest during the evening.

On the Cornell campus the males resort to a common roosting place at all times during the season that Robins are present. Contrary to Mr. McClanahan's observations, my findings are that the male does not feed the female while she incubates.

While incubating her eggs the female is silent but when leaving the nest or returning to it she may chirp a few times. The female usually takes the more aggressive part in defending the nest.

In moving the eggs the female rises from the nest hollow and turns them with her bill as she stands on the rim of the nest. The eggs may not be shifted during a period of 45 minutes, or they may be shifted as often as three times in 10 minutes. The time consumed in shifting the eggs is usually a matter of a few seconds, so brief in fact that it seems unlikely that all of the eggs of a set are rotated at one time.

The following field notes show the activities of incubating birds.

Nest no. 1. April 24, 1937. 3:00 P.M., began watching bird incubate eggs, which are one day advanced. She left nest at 3:10. During this 10 minute period she never shifted her position. She moved her head a few times from side to side and opened her bill twice as though "yawning." Just before she left nest her made (presumably) was heard to chirp a few times from dense conifers perhaps 40 feet away. A few chirps were heard from point where second bird was located during period from 3:10 to 3:15. At 3:15 bird flew to low branch of nest tree and hopped and flew to nest in a few seconds.

April 26, 9:00 A.M. Bird on nest. She sat silently until 9:05. Ran out 2 feet on branch west of nest. Returned to nest but didn't settle on it. A second or two later she ran 2 feet northeast of nest, flew chirping to tree 20 feet from nest, voided excrement. Flew to ground, but 2 minutes later flew to limb a foot from nest. A few seconds later she settled on nest. 9:10, a Chipping Sparrow fed in a semicircle about nest only a foot away chirping as it fed. Robin paid no attention to it. 9:20, yawned. 9:32, stood on rim of nest and with bill moved eggs. 9:50, bird flew silently from nest. 9:59, returned to nest tree alighting on branch three feet from nest gave a few low chirps, hopped to nest and settled on eggs.

Nest no. 41a. May 19, 1937, 5:02 P.M. Bird on nest. (Female marked with a white feather attached to tail). 5:04, bird flushed as truck backed up near nest. I sat in open 40 feet from nest. 5:10, male and female side by side in Red Pine 40 feet from nest and 25 feet from me. 5:11, female flew to top of barn on the side of which the nest was attached. She flew to nest and settled on the eggs. Tail bobs up and down continuously in the wind. 5:35, bird has shifted position. 5:40, male not seen in last half hour. Eggs about a week incubated.

May 24, 8:05 A.M. Female on. Auto turned around immediately beneath nest without bird flushing. She was less shy than on the 19th). 8:24, female flushed from nest flying off to north. At same time a male alighted on ground in pasture 40 feet west of nest. Female gave low "cucks" as she flew. Male fed awhile, sang a little from a low post. 8:27, female alighted on barn. Another Robin alighted on peak of barn beside her and there was a short fight. Both birds flying up two feet above the barn, locked in combat, and then alighting almost where they started. Female hopped along roof of barn to its edge and flew heavily to nest. She paused on rim of nest for a few seconds, but didn't turn eggs. Settled on eggs, moving first to one side and then the other before settling down, apparently to bring eggs into contact with her skin. Student walked directly beneath nest without flushing bird. 8:37, Robin sang on the telegraph wire 125 feet from nest. 8:51, three people talked only 20 feet from nest without flushing female. 8:53, female shifted position so rapidly that I failed to see the move. 9:00, female has not shifted since 8:53.

Nest no. 34 was used to run an experiment on the length of time that a female would sit on eggs which did not hatch. The female commenced incubation on May 3, 1937. On May 11 a set of eggs with dead embryos were substituted for those in the nest. The female sat on the nest for seventeen days, until May 20, when the nest was abandoned.

HATCHING OF THE EGGS

PROCESS OF HATCHING

The process of hatching usually becomes evident only when a small bump appears on the outside of the shell of an egg. This projection results from the picking of the shell by the embryo. The embryo uses the small pointed tubercle or egg-tooth located on the culmen near the tip of the bill to break out of the shell. The shell is fractured at one place, then the embryo rotates in the shell (or perhaps the parent rotates the egg) until it reaches another spot and here again fractures the shell. Usually the fracture does not produce a hole in the shell, the area around the fractured point merely being pushed out, although at times a definite opening is created. As a rule the embryo pips the shell only above the greatest circumference of the egg. At no time does the embryo puncture the top or cap of the egg. In breaking out of the shell a ring of fractures is made around the cap of the egg and this is finally pushed away. Often the two parts of the shell are nearly entire.

The rate at which the embryo taps the shell varies with the progress of hatching. At first the blows are scattered and faltering but as the embryo continues the taps become quite rhythmic. One egg was held in my hand near my ear and the number of blows struck during a minute were counted, and found to be ten. Another embryo tapped the shell 18 times on each of two minutes during which counts were made.

The structure of the shell changes as incubation progresses. A fresh egg shell is hard and brittle, but when a young Robin begins to peck its way out, the shell is thinner, less brittle, and it has an almost leathery texture.

A pipped egg was collected from nest no. 72 and found to weigh 5.5 grams. The embryo weighed 4.9 grams and the shell, the bloody membrane and a few drops of yolky fluid weighed 0.6 of a gram.

DURATION OF HATCHING

The time taken by the embryo between its first fracture of the shell of the egg and its breaking free of the shell is about 24 hours. A few eggs hatch in less than 24 hours and one took at least 36 hours.

DISPOSAL OF THE EGG SHELLS FOLLOWING HATCHING

The shells from which young Robins have hatched are removed from the nest almost as soon as the young are free. The fate of the shells is not always the same. Mr. Harold Axtell, of Cortland, N. Y., told me that on June 10, 1938, he observed a female Robin take a piece of egg shell from her nest and carry it 100 feet in her bill to a bare, grassless spot where she ate it. Seven minutes later she carried another piece of shell further away from the nest and ate it. Then the male flew to the nest, dug up a good-sized piece of shell and gave it to the female who flew away with it and devoured it also.

Mr. Axtell states that he has seen Robins carry away shells and drop them instead of eating them. On a few occasions I have found halves of egg shells containing bloody membranes and appearing to be shells from which young had hatched at some distance from the nearest Robin nest. Presumably these represent instances where the parents carried the shells from the nest and did not eat them.

Young

DEVELOPMENT OF THE YOUNG

The measurements used in the following account of the growth of young Robins were taken in the following manner:

Length—taken from the tip of the bill to the posterior-most part of the body. The posterior end of the body was used as the extremity in taking this measurement, until the tip of the tail grew beyond the end of the body, then the latter was used. *Wing*—taken from the bend to the structure which extended furthest distad. At first it was taken to the tip of the fleshy framework (the middle digit), later it was taken to the tip of he longest primary. *Tarsus*—taken as in adult. *Gape*—taken from posterior extremity of the mouth slit to the tip of the longer mandible. *Tail*—taken by placing a ruler against the upper surface of the tail and pushing it along the tail until the body was reached. It is actually a measurement from the insertion to the tip of the tail.

All measurements are in millimeters, and all weights are in grams. In the subsequent day by day account of the development of the young the following system of condensation had been adopted: W.=weight, L.=length of body, Wg.=wing, T.=tarsus, G.=gape, Tl.=tail, and I.=individual. The average figure is given after the abbreviation for the weight and each measurement. The minimum and maximum figures are given following the average and they are inclosed in parentheses. Finally the number of individuals weighed or measured is given.

The color of the down is constant throughout the period that it remains attached to the developing bird. The down is dull white on the basal 2 mm., the remainder being Pale Ochraceous Buff. The down seems to be fully mature when the young hatch. On a number of young the down was clipped close to the skin just following hatching and at no time did it increase in length. The down is of two types, a prominent much branched type and a short bristle-like type that is easily overlooked. The larger down varies from seven to eighteen millimeters in length. The shorter bits of down appear unbranched to the naked eye, but when viewed with a 14 X hand lens they are seen to be tufts of a few bristle-like filaments. These tufts are not more than a millimeter in length and are dull white in color. The short bristle-like tufts are found at the tip of each flight feather, except the innermost tertial, and at the tip of each tail feather. The location of the down is shown in Fig. 2. No down is present on the ventral surface.

The slit between the eyelids is open when the chick hatches, but the lids are held closed until the fifth day when they are opened now and then although not for long. By the seventh day the eyes are held open most of the time. It

is interesting to note that when the young first hatch the iris is below and behind the slit between the lids. Each day the eyeball moves slowly nearer to its final position. By the time the eye is first opened it is in place.

Gardner (1930) writes that young Robins have relatively low body temperatures. A rapid rise occurs during the period in the nest and at the time of initial flight temperatures approximating the normal for the species are found. In several instances very high temperatures were found in well-developed fledglings, in one case being over 110° F. which is somewhat above the mean for the adults. A follow-up reading in one young Robin readily demonstrated this rise. When two days old, July 5 at 5:30 P. M. (96°) it registered 104.3 which is however, a relatively high temperature for so young a bird. When eleven days old, July 14 at 5:30 P. M. (89°) the temperature had increased to 106.1.

Instinctive fear is first shown by young Robins in the interval between the sixth and tenth day. A young Robin studied particularly to determine when fear first appeared gave a sharp squeal on the sixth day that it had not given before. This call excited the parent Robins. The youngster, however, soon adjusted itself to being handled and showed no further evidence of fear. By the tenth day, however, the young one showed good evidence of fear. It tended to move away from me, loud sounds made it cringe. It kept its mouth open as

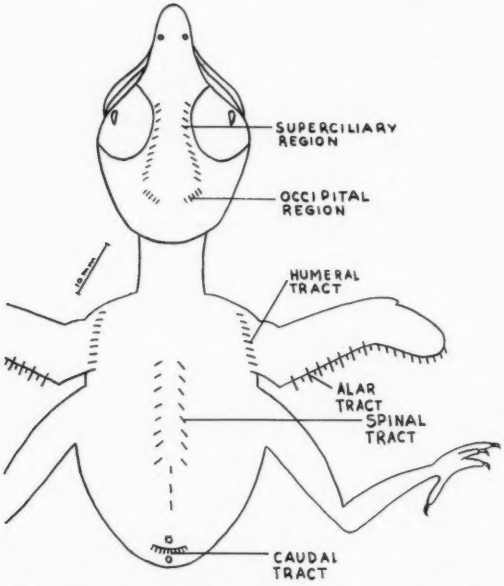

Fig. 2. Location of down on young Robin three days old.

if to strike me, but it neither struck me nor attempted to swallow my finger as it did when younger.

At hatching the egg-tooth is a white, rough, hard, and pointed tubercle located on the culmen about a millimeter back from its tip. Its base is less than a millimeter in greatest diameter. The egg-tooth seems to be a dead structure. The bill grows following hatching, but the egg-tooth remains constant in size. It is probably usually knocked off, this occurring sometimes during nest life but more often two or three weeks after the young has left the nest.

When the young are first hatched the tips of the two mandibles are often not even, one often extending a millimeter or more beyond the other. Sometimes the upper mandible and as often the lower extends beyond the other, but before the young leave the nest the two mandibles assume the relationship found in the adults where the upper mandible extends a little beyond the lower.

Some young produce a great deal of saliva.

Throughout the period spent in the nest the young has skin that is Baryta Yellow. The skin however is translucent and so the colors of the organs lying beneath it are visible. At first the organs lying beneath the skin show up plainly but as the young grow the body wall becomes thicker and by the time the young leave the nest only the pink of the flesh shows up through the skin.

The daily changes in weight and length of body, wing, tarsus and tail are shown graphically in figures 3, 4, and 5.

DAY BY DAY ACCOUNTS OF THE DEVELOPMENT OF THE YOUNG

At hatching.—W. 5.5 (4.1-6.7), 13 I.; L. 58.5 (50.0-62.0), 9 I.; Wg. 8.8 (7.5-9.5), 8 I.; T. 9.0 (7.5-9.5), 8 I.; G. 10.3 (9.5-11.0), 8 I.; Tl., no feathers yet present.

At hatching the young can raise their heads for food but only for a second or two. They usually raise their heads about every third or fourth minute. They cannot stand at this age but kick their feet in a haphazard fashion. The only sound given at hatching is a weak peep. When given most rapidly the peeps are only a second apart. The entire body of the bird is convulsed with each peep. Usually the young are silent at this age.

The feathers beneath the skin of the Capital Tract are dark blue. The rest of the body tracts show up light in color. The Alar Tract shows dark feathers. The Crural Tract does not show up yet.

The skin is Baryta Yellow, but as it is translucent the colors of the organs lying beneath it are seen. In the abdomen the gall bladder shows up greenish, the liver purplish red and the yolk looks orange. The bill is Orange-Pink, darkest in color near its tip. Along the basal half of the tomial edge of the bill the color is Baryta Yellow. The inside of the mouth is predominantly Light Cadmium. The floor of the mouth beneath the tongue and behind it is flesh-colored. The legs and toes are flesh-colored with a yellowish tinge due to the skin. The toes are a trifle more pinkish than the rest of the leg. The claws

are flesh-colored and have a fairly prominent blood supply. The skin descends only a short distance into the ear cavity.

One day old.—W. 8.0 (5.4-11.9), 29 I.; L. 67.0 (60.5-73.0), 18 I.; Wg. 10.0 (9.0-11.5), 18 I.; T. 10.0 (9.0-11.0), 17 I.; G. 12.0 (10.5-13.0), 16 I.; Tl., undeveloped.

The young are better able to raise their heads today, but they cannot stand. Only occasional faint peeps are heard; they are usually silent. The feathers show up under the skin in all tracts except the Crural. They are dull bluish

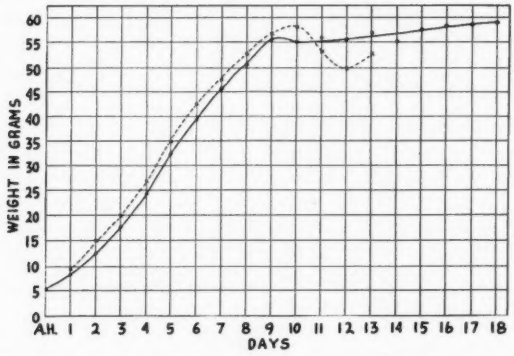

Fig. 3. Daily changes in weight of developing Robins. Unbroken line shows changes based on average weight of a number of individuals. Broken line shows changes of an individual from nest no. 73 and emphasizes loss in weight which often occurs shortly before young leave nest. A. H. = at hatching.

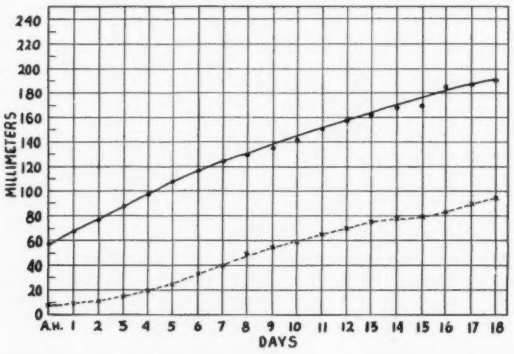

Fig. 4. Daily changes in the total length of body (unbroken line) and length of wing (broken line) of developing Robins. Measurement given for each day is an average based on a number of individuals. A. H. = at hatching.

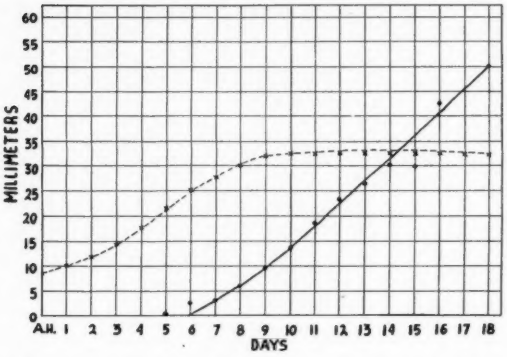

Fig. 5. Daily changes in the length of tarsus (broken line) and length of tail (unbroken line) of developing Robins. Measurement for each day is an average based on a number of individuals. A. H. = at hatching.

gray on all tracts on the dorsal surface and the Femoral Tract. The feathers are light colored below except for certain lines of dark dots near the center of the axillary region.

The culmen of the bird and the region in front of the nostrils is Pale Yellow-Orange. The leathery, flexible, tomial edge is Cream Color over its basal half. The lower mandible still has a pinkish tinge. The inside of the mouth is unchanged. The legs are flesh-colored; the toes are Napthalene Yellow.

Two days old.—W. 12.6 (8.4-17.5), 25 I.; L. 77.7 (71.0-85.0), 17 I.; Wg. 12.5 (11.0-15.0), 18 I.; T. 11.9 (10.5-14.0), 17 I.; G. 14.5 (13.0-17.0), 18 I.; Tl., undeveloped.

The head is more freqeuntly raised but never for more than ten seconds at a time A young one placed on a table top raised its head for food at intervals of a few minutes without any move on my part that might have served as a stimulus for such action. The young cannot stand, yet they are able to raise most of their bodies by using the backs of the tarsi and the belly. They keep up a low peeping through the closed bill.

The feathers appear prominently beneath the skin; they have elongated considerably since the day before and no longer appear as dots. The feathers are just showing up in the Crural Tract.

The culmen ridge is Vinaceous-Buff, except for the terminal one-fourth which is Light Orange-Yellow. The leathery, flexible, tomial edge is Ivory Yellow for its basal half. The rest of the bill is unchanged. The inside of the mouth is unchanged. The legs and toes are unchanged.

Three days old.—W. 17.8 (12.2-25.2), 24 I.; L. 88.5 (81.0-100.0), 17 I.; Wg. 15.9 (13.5-19.5), 17 I.; T. 14.7 (12.5-18.0), 16 I.; G. 16.6 (13.5-18.0), 17 I.; Tl., undeveloped.

The movements of the head are the same as on the preceding day. The young still cannot stand. The only sounds are occasional peeps. The feathers are dark blue but the yellow skin gives them a greenish cast. No feather projects above the skin. The color of the skin is unchanged but the yolk supply beneath the skin is much reduced so that the belly looks less orange.

The bill has lost any tinge of orange except along the tomial edge. A small patch of Dark Grayish Lavender has appeared in front of the nostrils. The flexible tomial edge of the basal portion of the bill is Ivory Yellow. The culmen is Ivory Yellow with a tinge of Dark Grayish Lavender. The inside of the mouth is unchanged. The leg and toes are unchanged except for the claws. The terminal two-thirds of the claws are still Napthalene Yellow but the basal third has become Quaker Drab. The skin has descended far into the ear cavity; the bottom of the cavity cannot be seen.

Four days old.—W. 24.3 (17.9-32.3), 23 I.; L. 98.1 (89.0-107.0), 16 I.; Wg. 20.9 (17.0-25.0), 16 I.; T. 17.7 (15.5-21.0), 16 I.; G. 18.6 (15.5-20.0), 16 I.; Tl., undeveloped.

The movements of the head are as on the preceding day. The young were not seen to stand yet. No sounds are given except occasional peeps. The iris is gray-brown in color.

The tips of the feather sheaths have appeared above the skin on all tracts except the Femoral. The sheaths are exposed for the greatest distance on the flight feathers.

The tufts of down on the Humeral Tract are borne on the tips of only the most distal feathers in this tract. The greater secondary coverts, numbers V through VIII, bear the large prominently branched tufts of down. All flight feathers bear a bristle-like tuft of down on their tips, except the innermost tertial.

The bill is as it was on the third day. The legs and toes are unchanged except that the Quaker Drab extends half way down the dorsal surface of the claws. The under surface of the toes are Napthalene Yellow.

Five days old.—W. 32.8 (23.7-39.5), 23 I.; L. 107.7 (95.0-115.0), 16 I.; Wg. 27.8 (22.0-37.5), 16 I.; T. 21.3 (18.5-25.0), 16 I.; G. 20.1 (16.0-22.0), 16 I.; Tl. 1.0, 2 I.

The movement of the head shows no change. The young are able to seize objects, such as a finger, at this age, which they were unable to do earlier. They attempt to swallow whatever they seize, treating it as food. They are still unable to stand. No new notes are given at this age.

In the Capital Tract the rictal bristles are the best developed feathers, having one millimeter of sheath exposed. No feathers in this tract have broken through the tips of their sheaths.

The sheaths of the flight feathers are the longest of all the developing feathers. No feathers in the Alar Tract have pushed through the tips of their sheaths except for the posterior rows of the margined coverts. The sheaths on

the lower surface of the wing are much behind those of the upper surface of the wing having just pushed out from the level of the skin. In the Humeral Tract a few feathers have broken through their sheaths. Many of the feathers of the Ventral Tract have just broken through their sheaths. The feathers of the Femoral Tract seem in almost all cases to have broken through their sheaths. The tips of the feathers of the Crural Tract are extending beyond their envelopes today. The upper tail-coverts are the longest feathers in the Caudal Tract. They are the only feathers in this tract that have broken through their sheaths. The sheaths of the feathers of the anal circlet have not yet pushed above the level of the skin.

The predominant bill color is Light Plumago Gray. The terminal 1.5 mm. of the bill is Maize Yellow. The tomial edge is Light Cadmium except for the expanded leathery basal portion which is Ivory Yellow. The leg color is unchanged.

Six days old.—W. 39.4 (32.5-45.9), 23 I.; L. 117.1 (108.0-125.0), 16 I.; Wg. 34.5 (29.0-42.0), 17 I.; T. 25.1 (22.0-29.0), 16 I.; G. 21.2 (16.0-23.0), 16 I.; Tl., 3.0, 1 I.

The young raise their heads as before. The birds rest on the backs of the tarsi and the belly which form a tripod for the support of the body. In addition to the peep of the preceding days the young often give a louder call, a squeal. This may mark the appearance of instinctive fear. This call excites the parents noticeably. At this stage the eye is open about half of the time, but not for long at a time. The iris is still gray-brown; the pupil is opaque or almost so and is dull and gray-blue.

Most of the feathers of the Capital Tract have broken through their sheaths. In the Dorsal Tract almost all feathers have pierced their sheaths. The feathers bearing down are just breaking through their sheaths, while most of the other feathers are much more exposed. The tips of the flight feathers have broken through their sheaths in some cases. In the Humeral Tract the feathers are just pushing out through the tip of their sheaths. The feathers of the Ventral Tract are just breaking trough their sheaths on the lower side of the head and neck, the feathers further back in the tract being more exposed. In the Femoral Tract all feathers are exposed. A rather peculiar condition exists in the Crural Tract. Only the tips of the feathers project beyond the level of the skin, the sheaths apparently remaining beneath the skin. In the Caudal Tract the rectrices show up as short rather thick sheaths, each with a bristle-like bit of down present on its tip. The coverts have all broken through their sheaths. The tips of the feathers are present in the region of the anal circlet, but as in the Crural Tract the sheaths appear to remain beneath the skin.

The bill is unchanged. The backs of the tarsi are Marguerite Yellow, the fronts approach Light Plumbago Gray, but blood vessels beneath give it a reddish tinge. Top of toes like front of tarsi, but the bottom of the toes is like the back of the tarsi. Tip and bottom of the claws Napthalene Yellow, the rest is Quaker Drab.

Seven days old.—W. 45.9 (36.2-58.8), 23 I.; L. 125.1 (110.0-136.0), 16

I.; Wg. 41.7 (35.0 49.0), 16 I.; T. 27.5 (23.5-31.0), 16 I.; G. 22.1 (17.5-24.0), 16 I.; Tl. 3.1 (1.5-7.0), 10 I.

The young can keep their heads raised over periods of half a minute. They can stand on their toes for a second or two. On this day they sometimes give a rather sharp "chi - urp." This seems to be a food call. The squeal given on the sixth day is stronger today. Tyler (1913) reports that at this age at the approach of the parents the young make ". . . . a little ticking sound, audible only when I am very near." The eye is usually kept open at this age. The iris has taken its normal position with regard to the opening between the lids. It is still gray-brown but getting browner.

The length of the feathers in the Capital Tract has increased. No great changes occur in the Dorsal Tract. The feathers bearing down are a little less developed than the others. All the feathers on the under surface of the wing have broken through their sheaths. The feathers of the Humeral Tract are well developed and the down is still present. In the Ventral Tract the feathers of the head and neck are less developed than those of the posterior part of the tract. The Femoral Tract is unchanged except for the increase in the length of the feathers. No notable changes have occurred in the Crural Tract. In the Caudal Tract the tail feathers (rectrices) have not broken through their sheaths.

The bill is largely Light Plumbago Gray except for the terminal two millimeters. The tarsi, toes and claws are unchanged.

Eight days old.—W. 50.9 (42.0-59.3), 21 I.; L. 130.8 (117.0-143.0), 15 I.; Wg. 50.3 (45.0-59.0), 15 I.; T. 30.3 (27.0-33.5), 16 I.; G. 22.8 (18.0-24.0), 16 I.; Tl. 6.0 (2.5-10.0), 13 I.

No important changes occur on this day.

Nine days old.—W. 56.3 (43.4-61.4), 19 I.; L. 136.2 (121.0-148.0), 15 I.; Wg. 55.8 (48.0-62.0), 16 I.; T. 31.8 (27.5-34.0), 16 I.; G. 23.3 (19.0-25.0), 15 I.; Tl. 9.5 (5.0-14.0), 13 I.

A peculiarity in the development of the young is that many of them reach a peak in their weight at this age and drop in weight for a number of days following this. Other young maintain the weight of this age for a number of days before showing any increase. This is not well shown in the average weights of a number of individuals but is shown in the graph of the weights of a young of nest no. 73 (fig. 3).

No good explanation has been given as to the cause of this drop in weight. It coincides with the period of greatest and most rapid feather development and McClanahan (MS. 1935) points out that the greatest loss in weight is roughly correlated with the individual showing the greatest increase in the length of the primaries. It has been suggested by Plumb (1884) that this loss in weight is due to infestations of external parasites, but the loss regularly occurs in individuals not parasitised.

Ten days old.—W. 55.2 (49.0-63.2), 19 I.; L. 143.0 (129.0-152.0), 15 I.;

Wg. 61.4 (55.0-67.5), 16 I.; T. 32.4 (29.0-34.0), 16 I.; G. 23.7 (19.5-25.5), 15 I.; Tl. 13.9 (10.5-19.5), 15 I.

This is the earliest age at which young leave the nest. Many of the larger, better developed young leave the nest before the smaller, less vigorous young. This accounts for some of the seeming discrepancies that appear in the following tabulations of the progress of development. For instance the figure for the average length is actually less for the 15th day than for the 14th day, however, eight individuals were measured on the 14th day and only three on the 15th day. In this case the birds with the greatest length had left the nest and could not be measured on the 15th day; no individual bird, of course, lost in length on the 15th day.

The young experience no difficulty in holding up and moving their heads. They do not stand on their feet, but lean back on their tarsi. They can run for quite a distance. The wings are used to help their progress. The calls used are the three already mentioned—the peep given at hatching and the sharp "chi - urp" are still given and the squeals are more rapidly repeated. No young of this age were seen to fly although it seems possible that they could for a short distance. The iris is dark brown with a hint of gray.

The feathers of the Capital Tract still bear down. In the posterior part of the Dorsal Tract down is still present, but it is gone from the anterior portion. The down is still attached to the feathers of the Humeral Tract. The Ventral Tract has feathers that are shorter on the average than the Humeral and Dorsal Tract. The Femoral Tract has feathers that are about the same on the average as those of the Ventral Tract. The feathers of the Crural Tract are only about half as long as those of the Ventral Tract. The rectrices are 2.0 mm. exposed beyond their sheaths.

The culmen is unlike the rest of the bill, being darker except for a light streak on the anterior half and reaching from the mid-point to 1.0 mm. back from the egg tooth. The bill is largely Light Plumbago Gray. The tomium is still light yellow on the anterior half, and cream-colored on the fleshy posterior half. The inside of the mouth has become darker, having changed from the Light Cadmium present at hatching to Cadmium Orange. The fronts of the tarsi are Neutral Gray. The floor of the toes and the backs of the tarsi are Light Buff.

Eleven days old.—W. 56.5 (51.6-61.1), 19 I.; L. 150.0 (138.0-162.0), 15 I.; Wg. 66.3 (61.0-72.0), 14 I.; T. 32.8 (31.0-34.5), 14 I.; G. 24.1 (21.5-25.5), 14 I.; Tl. 18.1 (15.0-24.0), 14 I.

The young can handle their heads in a capable manner, experiencing no difficulty in seizing any object in reach of their bill. They can spring up a distance of two or three inches; they use their legs in jumping and to some extent their wings. Usually they still sit on the backs of their tarsi. In running they can get up off their tarsi and place their weight on their toes. The peep heard at hatching was not heard at this age. No new calls were recorded. At this age the young snap their bill as though angry, but will not strike or grab a

finger or pencil, apparently they no longer confuse such object with food. The fact that they do not strike or peck indicates that they are not yet able to take offensive action. No young can fly more than a few feet and then only from some height to the ground.

The relationship between the length of the feathers in the Ventral, Humeral, Femoral and Crural Tracts is the same as yesterday. The bill is as it was yesterday except that the light area is less pronounced.

Twelve days old.—W. 55.5 (48.0-63.2), 14 I.; L. 158.4 (145.0-170.0), 11 I.; Wg. 71.6 (64.0-76.0), 14 I.; T. 33.5 (33.0-34.5), 13 I.; G. 24.7 (22.0-26.0) 11 I. ;Tl. 23.4 (18.0-28.0), 9 I.

The down is gone from the top of the head in many young.

It is interesting to note that the tarsus is larger than it will be when the young matures. The pulpy bones of the young of this age must contract for the tarsus sometimes shortens as much as a millimeter. The tarsus of an individual from nest no. 74 measured 33.5 mm. when it was 9 days old. It was collected when it was 26 days old and the tarsus measured only 32.5 mm. The average tarsus measurements for 28 adults taken at Ithaca was 33.11 mm., or 0.39 of a mm. less than for young of this age.

Thirteen days old.—W. 56.7 (52.2-63.2), 10 I.; L. 161.0 (152.0-173.0), 7 I.; Wg. 76.0 (68.5-81.5), 9 I.; T. 33.4 (32.0-34.5), 8 I.; G. 24.6 (23.0-26.0), 7 I.; Tl. 26.4 (21.0-30.0), 6 I.

At this stage in development the young usually stand on the entire backs of the tarsi, but they can stand on their toes. They are often silent; no new notes are given. Young of this age can jump and flap up six inches vertically. While the young can fly at this age, they cannot maintain a horizontal flight and are forced to alight within fifteen or twenty feet. The iris is Fuscous in color, as is often the case in adults.

Some young have most of the down still adhering to the Capital Tract. The sheaths are gone from a few feathers in the center of the crown, the rest of the feathers in this tract still have sheaths. In many young the Dorsal Tract is almost free of down. The Humeral Tract has lost most of its bits of down.

The darker color noted on the culmen three days earlier, Hair Brown, has spread over most of the bill. Around the nostril is a small area which has a purplish tinge. The culmen is the darkest part of the bill except for a light streak mentioned earlier. The tomia are Ochraceous-Buff. The bases of the tomia are still fleshy but getting firmer. The breadth of these fleshy, tomial edges is decreasing as they become firmer, more like the adult condition. The inside of the mouth is still Cadmium Orange. The tarsi and toes are unchanged, but the claws are Black except for the terminal millimeter and the floor of the claws which are dull yellow.

Fourteen days old.—W. 55.0 (51.8-58.2), 7 I.; L. 169.2 (160.0-180.0), 8 I.; Wg. 78.7 (73.0-87.0), 8 I.; T. 33.2 (32.5-34.0), 7 I.; G. 24.8 (24.0-26.0), 7 I ; Tl. 30.2 (26.0-33.0), 7 I.

No important changes on this day.

Fifteen days old.—W. 57.7 (55.6-59.7), 2 I.; L. 169.0 (165.0-172.0), 3 I.; Wg. 79.8 (76.5-85.0), 3 I.; T. 33.0 for each of 3 I.; G. 26.0, 1 I.; Tl. 29.0 (28.0-30.0), 2 I.

The young can handle their heads about as well as the adults They do not stand on the backs of their tarsi at this age but on their toes as do the adults. The young squeal loudly and often. The squeal is an almost continuous sound, yet varying rapidly in volume and pitch. Sometimes a single squealed note is given, sometimes a group of rapidly rising and falling squealed notes. At this age the young show much fight. While examining one individual it struggled continually and pecked accurately and with considerable strength. It seized my finger and pinched whenever possible. The young can fly at least 25 feet in level flight at this age. The iris is still Fuscous.

The down is present on the Capital Tract. Usually the down is gone from the Dorsal Tract by this time. About a fifth of each primary is still enclosed in a sheath, while the greater coverts are without sheaths. Most of the feathers in the Humeral, Ventral, Femoral and Crural Tracts show little or no increase in length. Many of these tracts are without sheaths and few sheaths in any tract are more than 2.0 mm. in length.

Most of both mandibles is Hair Brown in color. The culmen is the same as it was on the thirteenth day. The legs and toes are as they were two days earlier.

Sixteen days old.—(All data from an I. from nest no. 73.) W. 58.8; L. 185.0; Wg. 87.0; T. 33.5; G. 26.0; Tl. 42.5.

This young was located at a point 40 feet from the nest which it had abandoned late on the preceding day or earlier on this day. It flew 75 feet before it was captured. It squealed once or twice during the time that the weight and measurements were taken.

Eighteen days old.—(Data on same I. weighed and measured on 16th day given first under each heading.) W. 59.2, 58.3, 2 I.; L. 194.0, 188.0, 2 I.; Wg. 92.0, 97.0, 2 I.; T. 34.0, 31.5, 2 I.; G. 27.0, 1 I.; Tl. 50.0, 51.0, 2 I.

The young from nest no. 73 was 200 yards away from the nest in which it hatched. It was able to fly 100 feet. Only after fifteen minutes of constant chase was it captured. The tarsus and gape are of adult proportions in this young. There were still three wisps of down on the second young, two on the tips of feathers on the Capital Tract and one on a feather at the extreme posterior margin of the Dorsal Tract.

Twenty-seven days old.—(Data from only 1 I.) W. 77.4; L. 232.0; Wg. 121.5; T. 32.5; G. 25.0; Tl. 85.0.

At twenty-seven days old this young was of adult proportions in weight and tarsus measurements. At this age the young can fly and alight with the ease of adults.

Thirty-five days old.—(Data from only 1 I.; the average for adults is given in parentheses.) W. 88.7 (80.8); L. 250.0 (248.9); Wg. 126.0 (126.6); T. 35.0 (32.9); G. 27.5 (27.6); Tl. 92.5 (98.5).

When compared with the figures for the adult it is evident that the young is of adult proportions except for the tail. The weight and the tarsus measurements are both exceptionally high. By the time young Robins are 42 days old they are adult in all proportions considered in this study.

NEST EXERCISES OF THE YOUNG

When the young are one or two days old they remain quietly in the nest, usually moving only to hold their mouths open for food when the parent settles on or near the nest. As the young grow older they become more and more active. By the time they are ready to leave the nest they are very active. A nest holding three or more young is overcrowded after the young are ten days old.

The following fieldnotes give a picture of the actions of the young when they are about ot leave the nest. They were taken on June 7, 1937, at nest no. 41a when the four young were thirteen days old. The young left the nest on the following day.

3:32 P. M. 1 of young is standing up precariously on the edge of the nest. The young often extend their wings as though about to fly. They appear to find something among their feathers which they eat (Perhaps they eat the parts of the sheaths as they break away from the developing feathers; no external parasites were noted.) Frequently they have recourse to their oil glands. One young was almost pushed from the nest and had to flap vigorously to maintain its balance. 3:38, one young is on top of the other three. The actions of these young point to the fact that over-crowding is perhaps an important factor in causing the young to leave the nest. 3:51, 1 of young fell over the edge of the nest, but managed to scramble back by dint of much flapping. 3:56, young flap their wings vigorously every few minutes as they almost fall from the nest. Their begging note is a rather low, intermittent squealing sound. 4:07, young remained silent for two minutes. 4:09, uppermost young began preening.

At no time in my observations have I noticed a young Robin fight with one of its nest mates.

LENGTH OF THE PERIOD SPENT IN THE NEST

Table 7 gives data on the length of time that young spend in the nest.

TABLE 7.—Number of days young Robins spend in nest.

	No. of days spent in nest							
Year	9	10	11	12	13	14	15	16
1937	0	7	2	3	5	4	0	0
1938	0	0	0	1	6	3	2	0
Total	0	7	2	4	11	7	2	0

The results are not as uniform as might be expected. It is significant that the young studied in 1937 were subjected to much handling while being weighed and measured. Probably this is an important reason why so many

young left the nest so early. However, some of the young handled most frequently were among the last to leave the nest. In these latter cases the fact that the young were placed in traps in order to capture and band the adults may account for their tardiness in leaving the nest. In 1938 the young were not closely studied and the data for this year are therefore a better indication of the normal behavior.

Thirteen days is the average amount of time spent in the nest after hatching. At this age the young are incapable of sustained level flight. This fact accounts for the annual spring crop of Robin orphans and it is one of the times of greatest mortality in all of the life cycle.

The time at which the different young of a brood leave the nest is subject to some variation. Often all of the young will leave the nest on the same day, even when their ages vary by a day or two. At other times the older young will leave the nest a day earlier than the younger ones. However there are no cases in my experience where more than a day has elapsed between the time the first and last young left the nest.

Merely approaching a nest will at times send the young fluttering in all directions, when if undisturbed they might have remained a day or two longer in the nest.

Howe (1898) gives the length of time that a number of young spent in the nest. One brood left the nest in 11 days, one in 12 days, two in 15 days, and one in 16 days. He concludes that the usual period spent in the nest is 14 days. Tyler (1913) reports a nest where the young spent 12 days in the nest, and another where the young spent 14 days in the nest. Judson (1915) gives an account of two nests, in one of which one young left the nest on its 12th day and the other two on the 13th day, in the other nest the two young left on the 14th day. Allen (1928) states that a brood under his observation left the nest on the 15th day. Roberts (1932) records that the young spent 9 to 12 days in the nest. Hamilton (1935) reports nests where 4 young left on the 13th day, and 6 young departed on the 14th day.

The extremes of the length of time that the young spend in the nest are 9 and 16 days.

The young seem to leave the nest at any time during the daylight hours when not disturbed. Pearson (1910) writes of a brood which left the nest at 7:00 A. M. One of the young in nest no. 141 left the nest between 11:00 A. M. and 1:30 P. M. Wright (1918) reports a brood that left the nest toward evening.

Forbush (1929) states that in some cases the fledglings return to the nest for a few nights. There are no other reports at hand of the young returning to the nest at night.

CARE OF THE YOUNG

RELATIONSHIP OF THE SEXES

There is much individuality displayed by the males in the share of the care of the young which they assume. Ordinarily the male does his full share of the task of feeding the young. In fact during the first few days the female

often spends most of her time brooding the young and the male will bring most of the food to the young. Such was the case at nest no. 41a which I had under observation, and McClanahan (MS. 1935) states that this was true of a nest he studied. Allen (1928) states, however, that the male does not feed the young during the first two days. At a nest which Gabrielson (1922) observed, containing two young that were about to leave the nest, the female did all the feeding while the male spent much of his time singing from some nearby trees. At another nest which he observed the male fed the young 34 times while the female fed them only 19 times.

The urge which leads the parents to feed the young is stronger in the female than in the male. In banding adults attempts were made to trap them by placing the young in a trap which imprisoned the adults when they entered to feed their offspring. It was found that the female would enter the trap in all cases before the male. In fact of the five adults captured whose sex could be determined only one was a male. Often the male would come to the trap, but only on one occasion did he enter it.

My observations fail to show a single instance of a male brooding his young. A number of nests where at least one parent was banded was studied to determine the part which the male played in brooding the young. Tyler (1913) reported that the female broods the young, both during the day and night. Forbush (1929) records, however, that some males do their full part of brooding.

The female takes the responsibility of protecting the young from inclement weather, shielding them from the heat of the sun or from the rain. Forbush (1929) records an instance where a female attempted to shield her young from a pouring rain, but being unable to shed the torrent called loudly for her mate. The two birds stood on opposite sides of the nest, each placed its head over the other's back and successfully protected their young.

It is the responsibility of the male to care for the first brood as soon as it leaves the nest while his mate builds a new nest and starts to raise a second brood. Judson (1915) records a case where a female built a second nest and laid two eggs in it before the young left the first. Tyler (1913) and Forbush (1929) comment on this fact. The latter writes, ". . . When the first brood leaves the nest they are guarded and fed by both parents, but soon the mother bird leaves them to be cared for by her mate and prepares for another brood. . . . The young birds do not at once learn to feed themselves, but follow the male about with plaintive cries as if famished.

On July 3, 1937, a banded young from nest no. 61 was observed following its parents about on a lawn fifty feet from the site where the female was building a nest. The youngster was 28 days old and frequently begged for food from its parents neither of which fed it in the half hour it was under observation.

Both parents of nest no. 114 were banded with both metal and colored celluloid bands. The nest was visited 13 times and it was found that the male did not show up at the nest even once until the young were a few days old.

The distress cries of the female failed to bring him to her side. As both the male and the brood of an earlier nesting (the second) were marked it was determined that neither were in the vicinity of the nest. Presumably the male took his earlier brood to another region and when they were able to care for themselves he returned to help his mate with the third brood.

From the above data it appears that the young are dependent on the parents, and the male in particular, for less than four weeks. While young that are four weeks old do beg from their parents, they receive little assistance and are able to forage for themselves to a large extent. By the time that the first brood is five weeks old the attention of both adults is needed to care for the second brood which is hatched at about this time.

BROODING OF THE YOUNG

The act of brooding protects the young from the cold. As reported above it is usually performed by the female. At nest no. 41a on May 26, 1937, when the young were one day old the female was brooding the young 106 minutes out of 180 that the nest was under observation. On no occasion did the female stay on the nest without interruption for longer than 20 minutes. Usually the interruptions consisted of merely rising from the nest hollow and searching for excrement among the young. While brooding the female sometimes preened or searched for Mallophaga in her plumage. Often she left the nest after about five minutes spent in brooding. Two hours were spent watching this nest when the young were 13 days old and they were not brooded even once.

The young are brooded most when just hatched. In case of rain or cold weather, however, even large young are brooded. The female spends the night brooding her young until they leave the nest.

NEST SANITATION

An important part of the care of the young is keeping the nest clean. The excrement of the young is removed from the nest as soon as it is voided. Over the outside of the fecal matter is a sac-like coat of mucous which simplifies its removal. When the young are less than a week old these fecal sacs are usually eaten by the parents. After that time they may either be eaten or carried away from the nest and dropped. Tyler (1913) records that fecal sacs are sometimes eaten during the last day that the young are in the nest. The fact that these sacs are usually carried a hundred feet or more from the nest serves as a safeguard against their presence disclosing the location of the nest as would be the case if they were dropped over the edge of the nest.

On almost every visit to the nest with food the parents probe about among the young to locate and remove fecal sacs. Tyler (1913) suggests that the presence of the adults acts as a stimulus to the young to defecate. Certain it is that after being fed the young often rises up and passes a sac actually into the bill of the expectant parent. He believes that perhaps the parents satisfy their hunger by devouring these fecal sacs.

FEEDING AND THE FOOD OF THE YOUNG

As reported above the male usually helps his mate with the feeding and care of the young, although during the first few days his services are given less frequently, in some instances, than is the case later on.

During the first day in the development of the young in nest no. 41a observations were made on May 26, 1937, from 6:32 A. M. to 7:13 A. M. In this case the male did all the feeding the female spending the entire time in brooding. Perhaps the fact that the temperature was about 60° may have accounted in part for the length of time that the female spent in brooding. During this period the male brought food to the nest and fed the young himself six times. Usually the female left the nest when the male came with food, but once she merely stood on the edge of the nest as the male fed the young.

During the second day in the development of the above four young the nest was observed from 7:04 to 10:04 A. M. The young were fed during this period 15 times, ten times by the male and five times by the female. To the female fell the entire task of brooding and she cleaned the nest ten times while the male cleaned it only twice. In this three-hour period the young were fed on an average of every 12 minutes and the nest was cleaned every 15 minutes.

On June 6, when the four young were thirteen days old, the above nest was watched between 4:40 and 5:45 P. M. During these 65 minutes both parents fed the young 4 times or about once every eight minutes. The male cleaned the nest twice, the female once, thus it was cleaned about every 22 minutes.

On June 7, between 2:41 and 4:50 P.M., the young were fed only six times, five times by the female, and once by the male. For one period of fifteen minutes I did not observe the young. In the 114 minutes that the nest was observed the young were fed on an average of every 19 minutes, much less than yesterday. The nest was cleaned every 38 minutes. The young left this nest either later in this afternoon or on the next morning. The parents were both much shier than they were yesterday.

McClanahan (MS. 1935) states that the feeding of the young in a nest he observed carefully in July, 1935, was done by both parents, but mainly by the male for the female spent much time in brooding. The young were fed about every ten minutes. Copeland (1909) reports that during 15 hours spent in a blind on July 11, 1908, at the summer school of the University of Ohio, two young Robins were fed 67 times or about every 13 minutes. Gabrielson (1922) observed a nest containing two young about to leave the nest for 15 hours and 40 minutes continuously on June 30, 1913, at Sioux City, Iowa. His observations began at 4:20 A. M. and lasted until 8:00 P. M. During this period the young were fed on the average every thirteen minutes. Another nest studied in June, 1915, on June 11, 12, 16, 17, 18, and 21 for a total of 11 hours and 45 minutes gave evidence that the young were fed on the average every thirteen minutes.

The young are not fed in rotation. At times a young one will be so full of food that a morsel will remain in his throat and I have often seen the parents take food from the throat of one young and place it in the mouth of

another. This inability of the young to swallow when stuffed with food insures against overfeeding of some young and underfeeding of others. Gabrielson (1922) reports that the two young in the first nest he studied (see above paragraph) were fed equally, one being fed 26 times and the other 27 times.

Usually the parent feeds only one youngster on each visit to the nest. Gabrielson (in above citation) in studying a brood of three young found that on 28 visits only one young was fed, on 19 visits two young were fed, and on 7 visits all three young were fed.

The parent bringing the food to the nest usually feeds it to the young. Often the female rises from the nest hollow and stands on the rim of the nest while the male feeds the young. Jordan (1901) reports a female that took some of the worms brought in by the male and both parents fed the young.

Wheelock (1905) holds that the Robin feeds its young on regurgitated food. The following observations were made at a nest by a window in a home in Chicago, Ill. I quote the following paragraph from her account:

> On the first day the crops of the nestlings contained balls of partially digested earth worm and white grubs, very jelly-like and with much saliva. On the second the food was of the same character but mixed with darker masses which seemed to be the abdomen of spiders; no legs or other hard portions were found in it, however, until the third day, when two bits of spider legs and balls of grass were discovered. Early on the morning of the fourth day, an earth worm, thoroughly macerated, was given fresh to one of the nestlings. This was the first fresh food I had seen given. During the fourth day the food was all administered in a fresh state, and consisted of earth worms, grass, grubs, and various species of insects. It was warm, wet, April weather and earth worms were the most abundant food, which doubtless accounts for their occurring in such quantities in the food of the young. June broods that I have recorded have more often fed upon fruit, caterpillars, and grass-hoppers.

It may be the general rule that young are fed on regurgitated food for the first three days, but I have seen a male feed young not over a day old a cutworm which he brought to them in his bill.

Gabrielson (1922) classified the food fed three young during the period from June 11, to 21, when they were one to eleven days old, as follows: ". . . 8 cutworms, 46 larvae of various kinds, some of which may have been cutworms, 38 earth worms, 1 maybeetle, 2 other beetles, 1 grasshopper, 3 crickets, and 13 unrecognized forms were detected out of a probably greater number of forms." The young were fed fifty-three times. A nest containing two young about ready to abandon it was observed for 15 hours and 40 minutes on June 30, 1913, at Sioux City, Iowa. The young were fed 43 times and a total of 71 objects. The food identified was as follows: ". . . 15 crickets, 1 grasshopper, 5 maybeetles, 6 other beetles, 1 bug, 10 cutworms, 4 other larvae, 22 earthworms and seven or more insects so badly mutilated as to be unrecognizable. As many as four earthworms were counted dangling from the beak on one trip. . . ."

Hamilton (1935) in reporting on observation made on nestling Robins at Ithaca, N. Y., from 1930-1933 writes of their food as follows:

> The food during late May and early June consisted principally of cutworms. From the earliest period these larvae form a prominent share of the menu. From two to six,

depending on the size, are brouoght to the nest at one time. Usually two large cutworms represented an average meal throughout the day. By closely observing several pairs of Robins throughout the nesting season, it was possible to estimate the daily number of visits these birds paid to the nest. An average of ten visits per hour, from 5:00 A.M. to 7:00 P.M. accounts for 140 daily trips made by the old birds. Being extremely conservative we might reckon a hundred trips daily to be a fair average throughout the fourteen days that four sets of nestlings spent in the nest. This would entail 1400 trips by the parents in feeding the young.

In order to determine the quantity of food eaten by the young birds, the freshly fed cutworms, adult insects, worms, etc., were occasionally removed from the young with blunt forceps, immediately after being fed by the parent birds, and immediately weighed. This procedure was inaugurated while the young were but a day or two old, and continued on alternate days until the young left the nest. By this method it was estimated the birds brought to the young approximately two grams of food at each visit, or a daily feeding of 200 grams of animal matter to the nestlings, be they three, four, or five.

This estimate is high for the early days in the nest and low for the days immediately preceding the time of leaving the nest. It is thought to be fairly accurate and, at least, gives some clue to the amount of food eaten. Robins feed their young, apparently regardless if there be three or five, 3.2 pounds of food during the two weeks while in the nest. The observations were made several weeks before the cherries ripened and, because of this, the food consisted almost entirely of animal matter.

Birds take the most available food, providing it is acceptable to them. During an entire day in early June a pair of Robins brought to their young numbers of the large crane fly *(Tipula trivittata)*, which were everywhere common. The mating insects were easily caught, and frequently the bird would approach the nest with two, or even three pairs of these mated flies.

Eaton (1914) in writing of the birds of New York states of the food of young Robins that:

> .... They are fed with a great number of caterpillars, cutworms, white grubs and earthworms. As their appetite increases the old birds seem to resort almost exclusively to angleworms, as a plentiful supply of these can usually be obtained. As the young birds become nearly feathered, ripe cherries are brought them, if they have not left the nest before the cherry season arrives. I have watched the old birds feed a nestful of 4 young ones ripe cherries at the rate of 16 to 30 an hour, and the young birds every few minutes would shake their heads and pump their necks until they regurgitated the cherry pits which would rattle on the veranda floor like grape shot.... On several occasions I noticed that the old Robins brought half ripe cherries to the young who were unable to digest them in this condition and perished accordingly.

McIntosh (1922) places on record an account of an adult Robin which killed a garter snake that was 13 inches in length and twice attempted to feed it to a young one just out of the nest.

Table 8 shows the food of young Robins in the Ithaca, N. Y., region. It is based on a study of 15 stomachs which were taken between May 12, and July 10, 1937. The young ranged from three to thirty-five days old. The analyses were made by Messrs. L. W. Saylor and R. C. McClanahan under the direction of Dr. Clarence Cottam of the Food Habits Section of the Fish and Wildlife Service.

After each item is given the percentage by weight of the total food for the fifteen stomachs which it makes up and the number of stomachs in which it occurred. If an item makes up less than 1% of the total it is listed as a trace.

The following abbreviations are used: tr for trace, L for larva or larvae, and N for nymph.

TABLE 8.—Food of young Robins in the Ithaca, N. Y., region.

Items	Percentage	Occurrence
Animal Kingdom		
Lumbricidae (Earthworms)	15.0	5
Crustacea-Oniscus (Sow-Bugs)	1.7	2
Pseudoscorpionida (Pseudoscorpions)	TR	1
Araneida (Spiders)	2.3	5
Diplopoda (Millipedes)	3.1	5
Insecta (Insects)	44.1+	15
Acrididae (Short-horned Grasshoppers)	4.9	1+1L
Hemiptera (True Bugs)	.5+	4
Pentatomidae (Stink-Bugs)	TR	3
Lygaeidae (Cinch-Bugs)	TR	1
Nabidae (Nabids)	.5	2
Miridae (Leaf-Bugs)	TR	2
Homoptera (Leaf-Hoppers, etc.)	TR	2
Membracidae (Tree-Hoppers)	TR	2
Fulgoridae (Lantern Flies)	TR	1
Coleoptera (Beetles)	11.6+	14
Carabidae (Ground Beetles)	1.6	6
Cantharidae (Soldier-Beetles, etc.)	TR	2
Elateridae (Click-Beetles)	1.0	4+1L
Byrrhidae (Pill-Beetles)	TR	1
Tenebrionidae (Darkling Beetles)	TR	1
Scarabaeidae (Scarabeids)	3.5	9
Curculionidae (True Snout Beetles)	3.5	7
Lepidoptera (Butterflies and Moths) only larvae	24.7	12L
Diptera (Flies)	TR	1L
Hymenoptera (Bees, Wasps, Ants, etc.)	3.2+	5
Ichneumonidae (Ichneumon-Flies)	TR	1
Formicidae (Ants)	3.2	4
Unidentified insect larvae	TR	1
Unidentified insect debris	1.2	1
Traces of animal matter	4.0	
Percentage of animal matter	70.2	
Plant Kingdom		
Gramineae (Grass) blades, stems, roots	19.5	13
Moraceae (Mulberries)	3.2	1
Rosaceae (Roses etc.,) seed of Indian Strawberry	TR	1
Leguminosae (Pulse family) Clover-leaf	TR	1
Plantaginaceae (Plantain family) seeds	TR	1
Caprifoliaceae (Honeysuckle family) seeds	2.4	2
Compositae (Composite family) seed	.5	1
Unidentified vegetable debris	1.5	3
Traces of plant matter	2.7	
Percentage of plant matter	29.8	

A young Robin collected on June 17 when three days old had 96% animal matter in its stomach and the rest of the contents was bits of grass. These bits of grass are found in the stomachs of most young, sometimes being 45% of the total content. Probably this grass is brought in to the young along with

food which is captured in areas grown up in grass. Thus its presence is accidental and it is not an important food as its percentage seems to indicate.

Gravel was found in the stomachs of Robins three and four days old. In one case it made up 5% of the total content. It is probably necessary to grind up the hard body walls of some of the beetles and other insects fed to the young. How the young secures gravel at this early age is difficult to determine. Dr. A. A. Allen suggests that the gravel may have been in the alimentary canals of earthworms eaten by the young.

DEFENSE OF THE YOUNG

In defense of its young the Robin often shows considerable bravery. Against human beings its usual behavior is to call loudly at the intruder. Occasionally it supplements its outcry by hovering overhead, or even diving at one. In a few instances parent Robins have struck me as I approached a nest or removed the young for study, but in no case was the blow severe enough to draw blood.

Dubois (1920) reports that a female whose nest was nearby struck him at least twice, once she flew through an open window and into a room to grab his scalp with her claws. Peake (1904) writes of a female Robin sitting on the rim of a nest containing young and allowing herself to be petted. Jensen (1925) records an instance of an English Sparrow systematically robbing the young in a Robin nest. Robin adults are for some strange reason unable to cope with the depredations of the sparrow, these smaller birds even stealing worms directly from the bills of feeding adult Robins.

Forbush (1929) writes on this subject as follows:

> The bravery of Robins in defense of their young is well-known. Mr. Henry W. Abbott of Yarmouthport, Massachusetts, says that he was once assaulted by six adult Robins with berserker rage and feathered fury. The late Judge George W. Wiggin, formerly secretary of the Massachusetts Fish and Game Protective Association, said that one morning in June he saw a gray squirrel start to climb an oak tree in which a female Robin was brooding young in the nest. Immediately the male Robin appeared, followed by six or eight more, all of whom darted at that squirrel and pecked it until they had driven it out of the tree, over the lawn, and across the street. In defense of its young one Robin has been seen to put two Blue Jays to flight. Some Robins are very pugnacious during the breeding season and such individuals have been known to kill other birds, though possibly for good reasons.

SECOND BROODS

RELATION OF MATES

The two Robins which raised a brood in nest no. 1 remained mated during two subsequent nestings. Both of these birds were marked with metal and celluloid bands. Three female Robins were banded and they built subsequent nests close to the site of their first nests. In these cases the males were not banded and it cannot be stated as a fact that these females retained the same mates, but in as much as the males retain their territories throughout the nesting season, the probability is that these females had the same mates throughout the season. There are numerous instances recorded of birds which were partially albino or othrwise individually recognizable that have raised more than one brood of young in the same immediate vicinity in a season.

It seems very likely that a pair of Robins remains mated throughout the nesting season. However the following account taken from Forbush (1929) indicates that at times a pair may separate during the breeding season.

> The Robin is looked upon generally as a model of fidelity, constance and devotion to one mate. The following case may be one of the few exceptions which proves the rule. Reverend George E. Allen of Plainsfield, Massachusetts banded a female Robin which was feeding a brood of three young; a male bird which assisted her was also banded. On June 8, her young left the nest. She had already started a new nest and there were three eggs in that by the 13th. While feeding the young in the nest she was assisted by an unbanded male and also by an unbanded female, which also fed one of the immature banded birds of the first brood. The second brood left the nest on July 10; on the 14th the banded female was refitting the second nest in which three eggs were found July 25. Was this bigamy?

This account would have been more convincing had the original male been seen following his apparent separation from his first mate. It is possible that this male may have been killed after the departure of the first brood from the nest.

In the event of the death of one of the members of a pair the other seems to remate. The female of the pair building nest no. 42 was collected and the nest taken. In a couple of weeks a new nest was built on the site of the original one, presumably by a new mate of the male.

FREQUENCY OF SECOND BROODS

In all parts of its range the Robin seems to raise at least two broods. Even at the northern extremity of its range it raises two broods in spite of the shortness of the season.

RELATIONSHIP OF THE FIRST NEST TO THE SECOND

As pointed out in the discussion of the nest, the same nest is at times used in which to raise both the first and second brood. Usually the second nest is placed within 50 feet of the first, although in a few instances the second nest may be 200 feet from the first.

CHANGE IN THE TEMPO OF NEST BUILDING

The time consumed in building the first nest is about six days on the average, but it may be as much as two weeks. The second nest is built more rapidly than the first, it usually takes only about four days and there is much less variation in the length of time than in the case of the first nest.

COMPARISON WITH THE FIRST NESTING

The first nest is placed in conifers more often than in deciduous trees, whereas the reverse is true of the second nesting. For the exact figures on this relationship see the section entitled "Nest."

The chance of a nest being successful is more than twice as high for the second nesting as for the first. This subject is more fully discussed under the heading "Success in Nesting."

Fewer eggs are usually laid during the second nesting than the first. In

1937 and 1938, of 68 first nests observed, 39, or 57.3% held four eggs; of 42 second nests observed only 15, or 35.7% held four eggs.

THIRD BROODS

RELATIONSHIP OF MATES

As was pointed out in discussing the second broods a pair of Robins usually remains mated for the duration of the entire nesting season.

FREQUENCY OF THIRD BROODS

Few Robins raise three broods in a single season in the Ithaca region. The length of the season is just long enough so that if the first two broods are successful a third brood can be raised. Very few pairs of Robins succeed in raising two broods without meeting some mishap. Of those few which are successful not all raise a third brood.

In 1937 two pairs in which one or both of the members were banded were known to have raised three broods. Both of these pairs began the nesting season early and met with no setbacks, yet they did not complete their third clutches until July 9 and 10, respectively. A close search for Robin nests revealed that only five Robin nests held eggs after the fifth of July. One of the members of the pairs building one of these five nests was banded and it was known to have reared only one other brood. Twenty-seven pairs built nests in the area studied during the first nesting period. Thus there were four third nestings in an area where there were twenty-seven first nestings, or a ratio of about one third nesting to seven first nestings. In view of the fact that two of these third nestings might represent late attempts at raising a second brood it is evident that one in seven pairs represents the maximum proportion of pairs that raised three broods.

To the north of this region third broods are rare, and in the northern extremity of the range there are no records of third broods. Few records are at hand for third broods in the southern portion of the range, but from the length of the breeding season and few records at hand it is certain that three broods are sometimes raised. As the nesting season is longer in the south it is probable that three broods are more often reared there.

RELATION OF THIRD NESTS TO EARLIER NESTS

The pair which built nest no. 1 raised a brood and then built nest no. 71, fifteen feet to the southeast. Their third nest was almost 200 feet to the south of nest no. 1.

The pair raising a brood in nest no. 2 built nest no. 74, 40 feet to the west. A brood was fledged in nest no. 74, following which this pair built nest no. 113, 20 feet north of nest no. 74.

In both cases all three of the nests of each pair were within 100 feet of a central point which probably marked the approximate center of the territory of that pair. The territory set up at the beginning of the nesting season seems to be maintained without change throughout the breeding season.

COMPARISON WITH THE TWO EARLIER NESTINGS

The third nest is almost invariably placed in a deciduous tree or building. The third nest, like the second, is built more rapidly than the first.

The data at hand are too limited to serve as more than an indication, but it is significant that no nest of which I have a record held four eggs. Five nests found later than July 5, in 1937, all held three eggs.

Condition of the Gonads

TESTES

From the time of the spring arrival of the males their testes steadily increase in size until about the middle of April when they have usually reached their greatest size. This peak in enlargement seems to be maintained throughout the period of egg-laying. By the second half of June the testes of some males have begun to wane in size. Most of the males taken in July had testes that were reduced in size, although a male taken on July 27, 1937, had fully enlarged gonads.

During the latter half of March and the first half of April the testes of all male Robins which are in good physical condition are enlarging. Specimens taken on the same day do not always have gonads of equal size. No data were gathered which serve to explain these differences in development. Perhaps the gonads of resident males are of greater size than those of migrant males which would nest later on a more northern breeding area. Another possibility is that among the local nesting birds the older males had testes of enlarged size earlier than the younger males.

The testes of Robins are bluntly elliptical in outline. Normally they are grayish white in color, but occasionally one or both will be blackish. Dr. G. M. Sutton informs me that this condition is more common in members of the Thrush family than in most families. The cause of this dark color is unknown.

The two testes of specimen no. 19, taken on May 3, 1937, together weighed 1.0 gram, and measured 13.0 x 8.0 and 14.0 x 7.0 mm.

Table 9 gives the dates on which male Robins were collected and the size of their gonads. Where only one measurement is given it is the greatest diameter of the testis. In cases where the two testes were of equal size only one measurement for the length and breadth is given. Often the two testes differed in size and in these instances measurements for both gonads are given. All of these specimens were taken in or near Ithaca, N. Y.

For the sake of comparison the measurements of the testes are included for the entire period that Robins are present about Ithaca.

TABLE 9.—Seasonal change in size of adult Robin testes.

No.	Date collected	Measurements
1	February 5, 1939	3.0 × 1.5 and 2.5 × 1.5
2	March 20, 1938	4.0 × 3.0
3	March 20, 1938	4.5 × 3.5

4	March 22, 1939	2.5 × 1.5
5	March 23, 1939	2.5 × 1.5
6	March 25, 1939	4.0 × 2.5
7	April 3, 1937	4.0
8	April 3, 1937	4.0
9	April 4, 1937	7.0
10	April 5, 1937	5.5
11	April 5, 1937	5.0
12	April 6, 1937	9.0
13	April 6, 1937	5.0
14	April 6, 1937	9.0
15	April 10, 1937	9.5
16	April 10, 1937	5.5
17	April 17, 1937	12.0
18	April 19, 1937	10.5 × 8.0
19	April 25, 1937	13.0 × 7.0
20	May 3, 1937	13.0 × 8.0 and 14.0 × 7.0
21	May 6, 1937	12.0 × 8.5 and 11.0 × 9.0
22	May 6, 1937	12.0 × 9.0
23	May 22, 1937	16.0 × 10.0
24	May 22, 1937	14.5 × 12.0
25	May 23, 1937	10.0 × 8.0
26	June 13, 1937	13.0 × 9.0 and 10.5 × 9.0
27	July 10, 1937	8.5 × 6.0
28	July 10, 1937	4.5 × 2.5
29	July 19, 1937	13.0 × 1.0
30	July 21, 1937	4.0 × 2.5
31	July 24, 1937	3.0 × 2.0
32	July 25, 1937	3.0 × 2.5
33	July 25, 1937	3.6 × 2.5
34	July 27, 1937	2.5 × 2.0
35	July 27, 1937	12.0 × 9.0
36	October 8, 1937	2.5 × 2.0
37	October 8, 1937	2.5 × 1.0
38	October 13, 1937	2.5 × 1.5
39	October 17, 1937	2.5 × 1.5
40	October 24, 1937	2.5 × 1.5
41	October 24, 1937	3.0 × 1.5
42	October 24, 1937	3.0 × 2.0
43	October 24, 1937	2.5 × 1.5

OVARY

The ovary enlarges rapidly following the arrival of the females in spring. Eggs are sometimes laid only three weeks after the first females arrived from the south. During the nesting season the ovary is not of constant size. Just prior to the laying of the eggs the ovary is greatly enlarged by the presence of the yolks. At the time they are discharged from the ovary the yolks have a diameter of 13 mm. About half a dozen yolks are enlarged before any eggs are laid. A female taken on May 3, 1937, had yolks of the following diameters in the ovary: 13.0 mm., 10.0 mm., 7.0 mm., 4.0 mm., and three others over 2.0 mm. The weight of all the yolks in this ovary was 2.0 grams, the largest one weighing 0.9 of a gram, the next in size 0.4 of a gram, and the third heaviest weighed 0.2 of a gram. When fully enlarged (including the yolks) the ovary weighs about seven grams.

Following the deposition of a clutch of eggs, the yolks which were enlarged but not freed from the ovary decrease in size until none is over a millimeter in diameter.

The ovary has no uniform shape, being a more or less irregular mass of granular tissue. In measuring the ovary the greatest distance across the gonad was taken and often the shortest distance also. See table 10 for changes in the size of the ovary.

SUCCESS IN NESTING

The first nesting of the Robin is very often unsuccessful. The reasons for the high percentage of first nestings being broken up are many. Robins begin to nest early in the season when the weather is uncertain. Often freezing weather occurs and at such times many Robins desert their nests. Predation is higher at this time of the year than later on. The early nests are sometimes placed in deciduous trees. Before the leaves come out these nests are in the bare open and easily located by predators. Furthermore, food is scarce for most insects are not active, and few fruits are available. Many animals destroy

TABLE 10.—Seasonal changes in the size of adult Robin ovaries.

No.	Date collected	Measurements in millimeters
1	March 22, 1939	6.0 × 4.0
2	April 8, 1937	9.0 × 3.0
3	April 24, 1937	10.5 × 5.5
4	May 3, 1937	about 20.0
5	May 3, 1937	about 15.0
6	May 7, 1937	about 15.0
7	October 3, 1937	5.0 × 2.5
8	October 8, 1937	10.0 × 4.0
9	October 8, 1937	6.0 × 2.5
10	October 9, 1937	10.5 × 2.5
11	October 13, 1937	11.0 × 2.0
12	November 7, 1937	9.0 × 5.0

Robins and their eggs at this season but avail themselves of other food substances later on.

The first nestings, for the purpose of this study, are those nests which contained at least one fresh egg on or before May 15. Second nests are those in which the first egg was laid later than May 15. No attempt has been made to separate second and third nestings. In table 11 data are given on the number of nests whose fate was known, the number of these nests in which at least one egg was laid, and the number of these in which at least one young succeeded in leaving the nest. Only the first nesting was studied in 1938 as I left Ithaca before the record of the second nesting was complete. Data for the entire 1937 season are given.

TABLE 11—Success in nesting of Robin.

	1937					
	1st nesting		2nd nesting		Total	
Fate of nest	no. of nests	%	no. of nests	%	no. of nests	%
No. of nests whose fate was known	38	100.0	44	100.0	82	100
No. of nests in which at least one egg was laid	29	76	40	91	69	84
No. of nests in which at least one young hatched	17	45	34	77	51	62
No. of nests in which at least one young left nest	12	32	33	75	45	55

	1938	
	1st nesting	
Fate of nest	No. of nests	%
No. of nests whose fate was known	86	100
No. of nests in which at least one egg was laid	67	78
No. of nests in which at least one young hatched	37	43
No. of nests in which at least 1 young left nest	33	38

During 1937 101 young were raised in the 78 nests for which complete data on the number of young raised were secured. This is an average of 1.3 young per nest. This takes into account many nests which were begun and later abandoned or broken up. It is based on nests built throughout the entire nesting season.

If the average number of young raised per nest is 1.3 the number of young raised per year can be determined by computing the number of nests built per pair per year. This study shows that each pair built three nests a year. Thus each pair reared 3.9 young a year. The nests which produced no young are included in these calculations.

Of these 78 nests, young were raised in 42, thus 54% were successful. The number of young raised in the 42 nests was 101 or 2.4 young per successful nest.

In the foregoing table of the 1937 season it appears that 69 of the total of 82 nests, or 84%, had eggs laid in them. Some of the 16% of the nests which did not have eggs laid in them were abandoned soon after they were begun. In fact the beginning of a nest would often disappear soon after it was discovered. Probably the nest material was moved to a new site where another nest was begun. The factors causing Robins to abandon their nests were not determined with certainty. It often appeared that close inspection of a nest that was just started was sufficient to drive the birds from this nest to a new site. The attachment of a pair of Robins to its nest grows stronger with the progress of the nest history. Nests in the process of construction are deserted with much greater frequency than those containing eggs and nests containing young are very rarely deserted. Twice female birds which were incubating eggs were captured on the nest at night by the use of a flashlight and in both cases they deserted their eggs. However a female caught at night in the same way as she brooded a single large young did not desert her nest.

Of the above 69 nests in which one egg or more was laid, 51 later hatched

at least one egg. Thus 22% of the total 82 nests were broken up during the incubation period. This period is much longer than the period of nest building during which 16% of the nests failed. The cause of failure during nest building is usually desertion, while during incubation it is usually predation.

Of the 51 nests in which at least one bird hatched, one young at least was fledged in 45 instances. Thus in the period that the young were in the nest 7% of the total number met failure. The periods of incubation and that during which the young are in the nest are roughly of equal length. During the latter period almost no nests are deserted, the failures being due to predation.

Potter (1915) in a study of the nesting season of certain species of birds made at Camden, N. J., between 1912 and 1915 found that of fifteen Robin nests which he studied, only four, or 27% were successful. Only the Rough-winged Swallow and the Song Sparrow had less success in the eighteen species he observed. This is a slightly lower percentage of success than that for the first nesting period at Ithaca, and only about a third as successful as the second nesting period for 1937.

Data on 81 nests show that at Ithaca in 1937 of the 36 nests which failed, 19 were abandoned and 17 were broken up. Five of the nests that were abandoned seem to have been deserted due to my having visited them too often. The destruction of none of the nests could be attributed with certainty to man.

The predators were not actually witnessed at work in a single instance. Blue Jays and Crows were seen often near nests and once a Screech Owl was heard calling near a nest which was broken up. Cats were common in the area where the study was made. The two mammals which were most numerous in the region were the Chipmunk and the Red Squirrel. Once a Chipmunk was seen in an empty Robin's nest and Red Squirrels are known to prey frequently on their eggs or young.

Potter (1915), in a study referred to above, found that four nests were destroyed by man, four by English Sparrows, and three by unknown agents. He found that the English Sparrows drove the Robins from the latter's nests and proceeded ot build their nests on top of the appropriated nests. It is indeed a puzzle that so small a bird could drive one the size of a Robin from its nest.

In 1937 and 1938 studies were made of the fate of a number of Robin eggs. The findings are given in table 12.

TABLE 12.—Fate of Robin eggs.

Fate of eggs	1937		1938		Total	
No. of eggs in complete sets laid	132	100%	127	100%	259	100%
No. of eggs hatched	86	65%	71	56%	157	60.6%
No. of young leaving nest successfully	70	53%	61	48%	131	50.5%
No. of eggs which did not hatch through infertility or death of embryo	12	9%	6	5%	18	7%

Nice (1937), in her excellent work on the Song Sparrow, presents in table XVII, p. 143, the results of numerous studies of the nesting success of birds which were for the most part Passerine species building open nests. The per-

centage of successful nests in 814 reported was 45.9 (374 nests). The highest percentage of successful nests was 53.1 reported by Potter from Pennsylvania.

The percentage of successful nests in my study of the Robin during the year 1937 was 55, which is higher than that of any of the studies reported. It is noteworthy that during the first nesting the Robin had a perecntage of only 32 in 1937 and 38 in 1938.

In Mrs. Nice's table 857 young were fledged from 1,994 eggs, thus young were fledged from 43.0% of the eggs laid. During 1937 and 1938 the writer determined the fate of 259 Robin eggs that were laid in complete sets. From these eggs 131 young were fledged, or young were fledged from 50.5% of the eggs. On this basis also the Robin is more successful than the average Passerine species, in fact the highest percentage of success listed in her table was 46.7 for a study of 11 species made in England and reported by Baron.

Thus the nesting success of the Robin is very high for a passerine species building an open nest, whether it is calculated on the basis of successful nests or the relation between the number of eggs laid and the number of young fledged from them.

In 1937 I studied 82 nests and in 13 of these no eggs were laid. Of the 69 Robin nests which contained eggs, young were fledged in 45, or 65%. During the second nesting of 1937 44 nests were studied and eggs were laid in 40 of them or 91%. Of the 40 nests in which at least one egg was laid, young were fledged in 33 nests or 82%.

It is possible that the ready desertion of nests in exposed positions where molestation is frequent and the subsequent choice of a more secure site play an important role in the high degree of success enjoyed by the Robin.

Weaver (MS, 1938) reports on the nesting success of the Wood Thrush at Ithaca that of 15 nests studied young were fledged in 7, or 47%. In 1938 51 eggs were laid and young were fledged from 22 of them, or 43%. These results are close to the average for passerine species as given by Mrs. Nice (successful nests, 45.9%; young fledged from eggs, 43%). The results of Mrs. Weaver's study indicate that the Ithaca region is not an unusually favorable location for nesting passerine species. However, the findings of Potter (1915) at Camden, N. J., show that the Robin is not always a highly successful species.

In Mrs. Nice's study of the fate of 854 eggs of the Song Sparrow she found that 5.7% of them were sterile or addled. Of 259 Robin's eggs whose fate was determined 18, or 7% were sterile or addled.

The data on roosting during the nesting season have been published (see Howell 1940).

NESTING IN CAPTIVITY

Prior to 1900 Robins were a favorite cage bird. Nehrling (1893) writes of what fine bird pets they are; in a roomy cage they make a ". . . . delightful sight." Barrows (1884) gives an account of a captive female which laid several sets of infertile eggs. He goes on to state that ". . . she, however, adopted any young birds, of whatever species, put into her cage, and in every case reared the young successfully."

LENGTH OF THE NESTING CYCLE

The length of the nesting cycle is here taken to be the length of time between the laying of the first egg of one nesting and the laying of the first egg of the following nesting in cases where a brood is successfully raised during the first nesting. The female of nest no. 1 laid the first egg on April 18, 1937; four eggs composed the complete set. The young left this nest on May 16. The first egg of her next nesting was laid on May 25. Thus the cycle was completed in 37 days. A third nesting was undertaken by this pair and the first of their three eggs was laid on July 7. In this case the cycle was longer taking 43 days or 6 days longer than the first nesting.

The first of the four eggs in nest no. 2 was laid on April 23, 1937. The young left this nest on May 19. The first of the two eggs laid in this pair's second nest was laid on May 31. Thus the cycle was completed in 38 days. The young left the second nest on June 24. A third nesting was undertaken and the first of three eggs was laid on July 8. In this case the cycle was 39 days in length, one day longer than the first cycle.

The nesting period is defined here as the time elapsing between the date on which nest-building begins and the date on which the last young leaves the nest. This period is usually longer for the first nesting than for subsequent nestings owing to the fact that usually the first nest is constructed more slowly than later ones. Thus in the case of nest no. 120 the nesting period extended from about March 28, when nest-building began, until May 16 when the young left the nest. This is a period of 49 days. The second nest of this pair was begun about May 20 and the young left the nest on June 16, a period of 27 days. In this case the second nesting period was 22 days shorter than the first.

Howe (1898) gives the length of a number of nesting periods as follows: 45 days, 38 days, 36 days, 35 days, and approximately 30 days, while the average is 37 days.

Summary

The American Robin (*Turdus migratorius* L.) has a vast nesting range indicating its wide toleration of varying habitats. Food and water are much more important factors than cover in determining the nesting range.

The male seems to select the nesting territory. Both sexes return to the general vicinity of the territory on subsequent years. The smallest territory that can supply all of the needs of a pair of Robins and their brood is about half an acre; where the territories are smaller the parents secure some of their food outside of the territory, often on a common feeding area. Territorial battles between male Robins are brisk but neither participant is seriously injured. Occasionally a male Robin has two mates which share a common nest in which each lays a clutch of eggs.

In the courtship of the Robin both voice and display are important. While displaying the male spreads and elevates his tail, shakes his wings, and inflates his throat. Both the display and mating usually occur on the ground.

The Robin begins to sing earlier than most species and continues to sing

later each day. Some individual Robins may be heard singing at any season of the year. Two periods of song occur each year, the first in the spring and early summer and a second briefer one in late September and October.

Throughout its range the Robin is one of the earliest passeriform species to nest. At Ithaca, N. Y., most first clutches of eggs are laid between April 20 and May 5, second clutches between May 25 and June 5, and third clutches between July 5 and 15.

Both birds of a pair work together in selecting the site for the nest. Robin nests are occasionally placed on the ground although they usually are in trees or on structures made by man. Most nests are within ten feet of the ground. Early in the nesting season evergreens are used as nest sites more frequently than deciduous trees, later the reverse is true. The nest is usually built by the female. Robin nests have an outer foundation, usually of grass, a middle layer of mud, and a lining of grass blades. Early in the nesting season building a nest requires about 5 or 6 days, later nests 2 or 3 days. The nest is usually bowl-shaped and is greater in breadth than height. Some pairs of Robins raise two broods in the same nest in one season. Occasionally a number of nests are built one on top of another. Individuals sometimes build a number of nests or partial nests within a few feet of one another at the same time or in the course of one season. Cowbird eggs are systematically removed from the nest by the parent Robins.

The Robin usually lays three or four eggs; four being the commoner number during the early part of the nesting season and three during the later part. Sets of five eggs are uncommon, sets of six eggs are rare, and larger sets are usually the product of more than one female. The eggs vary in color from Deep Bluish Glaucous (light colored) to Nile Blue (deeply colored). The average measurements of 30 eggs from Ithaca, N. Y., was 28.4 mm. (length) by 20.7 mm. (width). Fresh eggs average 6.26 grams in weight. Eggs are usually laid about 10:00 A. M. When a Robin nest containing a set of eggs is destroyed another nest is often built and a set of eggs deposited in it within 10 days. Incubation usually lasts thirteen days; the extremes of duration are 11 and 14 days. The female usually carries out incubation without assistance from the male. The process of hatching usually lasts about 24 hours. Following hatching the egg shells are removed from the nest by the parents and may either be eaten or discarded.

The down of young Robins is Pale Ochraceous Buff. It is fully mature when the young hatch. For a brief summary of the daily changes in the weight, body length, wing, tarsus, and tail of the young see figures 3, 4, and 5. Many young undergo a temporary loss of weight during the ninth or tenth day. The young usually spend thirteen days in the nest; the extremes are 9 and 16 days. The male usually does his full share of feeding the young, but takes little or no part in brooding them. Both parents share in the disposal of the excrement of the young which is eaten or carried some distance from the nest and dropped. A study of the stomachs of 15 young collected at Ithaca, N. Y., showed the food to be 70.2% animal matter and 29.8% plant matter.

Two broods are usually reared each nesting season throughout the range of the Robin. The two members of a pair usually remain mated for the duration of a nesting season. Usually the nest used for the second brood is within 50 feet of the first nest. At Ithaca, N. Y., a few pairs rear three broods in one nesting season.

Tables 8 and 9 show the seasonal changes in the size of the testes and the ovary.

In 1937 the success of 82 Robin nests was studied. Of these 45 (55%) fledged at least one young. Only 32% of the first nests were successful, while 75% of the seconds nests (those in which the first egg was laid after May 15) succeeded. This is exceptionally high nesting success for a passerine species building an open nest. 7% (18) of 259 Robin eggs which should have hatched failed to do so because they were either sterile or addled.

The time elapsing between the beginning of the building of the nest and the the abandoning of the nest by the young varies from 27 to 49 days. When a brood is raised from a clutch of eggs the next clutch is laid about 40 days after the laying of the first clutch.

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Habits of Captive Marten

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Introduction

The marten *(Martes americana* and *M. caurina)*, commonly known in the fur trade as the "Hudson Bay sable," has been the subject of numerous breeding experiments at the U. S. Fur Animal Experiment Station for many years. In 1913 the former U. S. Bureau of Biological Survey started preliminary experiments with these animals at Pritchard, Idaho. When the fur farm at that place was abandoned the martens were shipped to Washington, D. C., where they were kept in the National Zoological Park for a short time.

After the establishment of the Bureau's experimental fur farm in the Adirondack Mountains near Keeseville, New York, in August 1916 six martens were shipped there from the National Zoological Park in Washington. Later, in August 1923, when the experimental farm was moved to Saratoga Springs, New York, three male and three female martens were moved to the new location. Thus, with the exception of a short time in 1915 and 1916, martens have been the object of continuous study at the fur animal experiment station from 1913 to the present time. This work is being continued by the U. S. Fish and Wildlife Service. Such study has included the compiling of information on general characteristics, breeding and feeding habits, production, longevity, whelping dates, size of litters, and the growth and management of the weaned kits. All data in the following report have been taken from the records of the fur animal experiment station at Saratoga Springs, New York, and from personal observations by the authors while employed there. The martens described in this article can all be traced back through breeding records to wild caught animals from Idaho and Wyoming, so they are probably of the subspecies *Martes caurina caurina* (Merriam).

General Characteristics

The marten is an animal of indescribable beauty, particularly in late September and October when the winter pelage with its brilliant orange breast and contrasting dark brown covering on the head, neck, body, and extremities is beginning to appear. The insatiable curiosity of these animals renders them comparatively easy to tame, although this same characteristic reacts to their detriment by making them very easy to trap.

The length of the head and body may vary from 15 to 18 inches, while the tail may be from 7 to 9 inches long. The weight of adults may vary from 700 to 1,300 grams or more. In specimens from California it was determined that 12 males averaged 35 oz. (995 grams), and 4 females, 26 oz., or 738 grams (Grinnell, Dixon, Linsdale, 1937).

Female martens are excellent mothers. Of the 52 kits whelped at the station only six have failed to live to weaning age, one of these being born dead and four others dying when about one month old. Because of this deep seated maternal instinct it has been the policy at the station to avoid in so far as possible any disturbance during the first month following parturition.

Fur Characteristics

The normal winter coat of the marten is a deep reddish brown dorsally, becoming distinctly paler on the face, inside of the ears, and the upper throat. The ventral region is paler than the lateral and dorsal areas. Perhaps the most striking feature is the yellowish white or orange tinted throat patch. Evident at once is a great individual variation in the extent of the throat patch. Its shape, always irregular, in several specimens was restricted to a number of detached spots on the lower throat and breast, while on others it became a solid patch extending from the upper throat to the abdominal region. On a prime winter pelt the tail and legs become nearly black on some individuals, for there the dark guard hairs appear to be much more numerous than elsewhere on the body. Pelage on the body consists of long, dense underfur with only a thin covering of fine guard hairs which do not detract from the soft, luxurious quality of the pelt.

The underfur fibers are straight near the base, but a waviness or "crimp" is found in the central portion of the hair shaft. The guard hair appears straight throughout its entire length. Guard hairs are short in relation to underfur length, seldom being over twice as long as the underfur fibers.

Hair length measurements obtained through the use of a small hand rule on the mid dorsal line (lumbar region) of male No. 40 revealed an average underfur depth of 19 mm., and a guard hair length of 35 mm. Measurements from the same area on seven study skins taken from both wild caught and ranch raised martens gave underfur depths of 20, 23, 24, 21, 20, 22, and 24 mm., and the maximum guard hair lengths of 45, 41, 38, 40, 37, 41, and 47 mm. respectively.

The longest guard hairs are found on the tip of the tail. Their lengths were 83, 91, 66, 68, 84, 97, and 94 mm. Tail diameters of prime winter pelts averaged 3 inches, being 72, 70, 61, 75, 79, 76, and 72 mm. at a point midway between the base and the tip of the tail.

Seasonal variations between summer and winter pelts are pronounced. Summer pelts have a faded rough, harsh appearance. Shedding of the entire guard hair covering takes place in late spring, and the underfur becomes less dense. The shedding of guard hair is particularly noticeable on the tail, its cylindrical, bushy appearance of winter becoming almost "rat-like" in summer. Loss of hair in the spring months appears to be gradual. When the marten nest boxes were cleaned in July many fine underfur fibers were found mixed with the straw which filled the nests. Pelage color changes from dark brown to

light tan during the summer. It is believed that summer sunlight is at least partially responsible for the faded condition of the summer pelt.

The work of Grinnell, Dixon, and Linsdale (1937) on the Sierra Nevada marten in California states that there is only one complete annual molt in the marten. From observations made in New York growth of new fur appears first on the tail tip and later on the legs. The middorsal region and the face are the last to grow the winter coat. In 1941 new guard hair on the tail tip was first observed on September 9, shortly after the termination of breeding activities. Over a six year period (1935-41) it has been noted that growth of new fur may be seen as early as September 1, but on one occasion did not appear until September 21. It should be emphasized, however, that considerable individual variation exists in this respect. Hair growth is nearly complete by mid-October, giving the marten a prime appearance a month to six weeks earlier than was the case with minks and foxes kept at the same station. Two subadult martens born April 12, 1941, had noticeably longer fur than the adults, and were completely furred out at an earlier date. Pelts of adult martens seem to become paler with increasing age.

According to Brassard and Bernard (1939) at birth young martens are reddish and only slightly covered with fine yellowish hairs. The appearance of dark gray stripes was noted eight days after birth, but the intensity of these markings was not equally well shown in every litter. On the shoulder the dark stripes run crosswise while on the back they run parallel with the body. These markings, most prominent at sixteen days, disappeared at 20 days. The general color up to three weeks is a dark gray, after which time the pelt becomes brownish.

Longevity

Although a number of the martens kept at Saratoga Springs, New York, have died very suddenly from unknown causes, and others have died as a result of injuries received during the mating season, evidence available at present indicates that the marten is a remarkably long lived animal and normally could be expected to live and reproduce for at least ten years.

One male, born April 6, 1927, at Saratoga Springs, New York, sired the one litter born in April, 1938. Litters have been produced by females three to nine years old. Wendnagel (1929) records data on a female European spruce marten which lived in captivity for at least 15 years.

Table 1 shows the ages reached by a number of martens kept at the station.

The Reproductive Cycle

It is believed that the failure of the marten to produce young in any considerable numbers under the artificial conditions prevailing on most fur ranches has been at least partially responsible for the fact that so few of them are raised in captivity. Certainly the interest evinced in this animal indicates

that large numbers would be raised if production similar to that obtained in the fox *(Vulpes fulva)* and mink *(Mustela vison)* could be assured.

TABLE 1.—Longevity of Marten.

Marten No.	Sex	Date Whelped	Date of Death	Age
2	Male	Wild caught, August, 1916; whelping date unknown.	9/13/26	At least 10 years.
6	Male	Wild caught, August, 1916; whelping date unknown.	9/11/26	At least 10 years.
23	Male	Wild caught, Dec., 1926; whelping date unknown.	1/4/37	At least 10 years.
29	Male	April 6, 1927	7/27/38	11 years.
40	Male	April 17, 1930	12/12/41	11 years.
44	Female	April 27, 1931	9/17/40	9 years.
49	Female	April 18, 1932	Living	10 years.
50	Male	April 18, 1932	5/17/41	9 years.
51	Male	April 18, 1932	Living	10 years.
52	Female	April 21, 1932	8/28/40	8 years.

A study of the station records shows that from 1920 to 1941, inclusive, if each female marten two years of age or over had produced a litter of young each year, as would logically be expected, an estimated 100 litters of marten kittens would have been whelped, instead of the 20 which actually arrived. The indicated 80 percent failure in litter production over the 21-year period in which the studies were made has unquestionably had a deterrent influence on those who might contemplate beginning raising these animals.

Breeding Habits

For a number of years it was supposed that the mating season of the marten was similar to that of the mink *(Mustela vison)*. Not only do they belong to the same family *(Mustelidae)*, but some evidence was presented by trappers and hunters that martens had been actually observed mating in January and February.

Ashbrook and Hanson (1927, 1930), after several years of observation, determined that the normal mating season of the marten was in July and August, and that the young were whelped the following April. The gestation period was thus set at from 259 to 275 days. Data on 17 litters whelped since

that date have completely verified these findings. It is difficult to determine exactly the length of the gestation period since females have been observed to mate a number of times over a two or three week period. However, two instances of single fertile matings at Saratoga Springs gave gestation periods of 261 and 276 days.

Adult male and female martens usually live together amicably throughout most of the year, and it is only during the latter part of the mating season that fighting becomes common. Females are apt to be antagonistic towards each other during the mating season, particularly when one or the other approaches the estrous period. This antagonism is demonstrated by bitter fighting, often resulting fatally.

Certain males have proven extremely rapacious. Of 18 adult females dying at the station, 9 have succumbed during the mating season to injuries resulting from fighting. Whether the close confinement of these animals as compared with their natural environment has intensified this ferociousness during the breeding season is not known. Male martens usually fight savagely when they encounter each other.

Length of the Mating Season

From the data assembled in Table 2 it can be seen that extreme limits in the active breeding season are July 10 to September 2, and that the length of the mating season may vary from 24 to 46 days in any given year. That the European species are similar in this respect is verified in the statement by Schmidt (1934) that the rut period lasts from June 20 to August 20. In normal seasons at Saratoga Springs most of the matings were found to occur during the month of July, although in 1941, 27 of 54 observed matings (50 percent) were noted in August.

TABLE 2.—Length of Marten Mating Season, 1935-41.

Year	Earliest Mating	Latest Mating	Length of Mating Season
1935	July 13	August 23	42 days
1936	July 21	August 16	27 days
1937	July 12	August 4	24 days
1938	July 18	August 21	34 days
1939	July 17	September 2	46 days
1940	July 10	August 21	43 days
1941	July 18	August 29	43 days

Changes in External Genitalia

External signs of the approach of the mating season are shown by changes in the sex organs of both sexes. The recent work of Enders and Leekley (1941) upon cyclic changes in the vulva of the female marten has revealed that the vulva swells and changes in color as they approach estrum. They observed that copulation tends to take place at the time of maximal swelling. A few females, however, will copulate before and after the maximal swelling is attained. The vulvar swelling is fairly well maintained in some females and is fully maintained in others for the duration of the breeding season. While the vulva of some females remained distended for a month or more in 1941 there appeared to be a periodic fluctuation between dates when matings occurred. Copulations were recorded for 3 or 4 successive days, followed by a quiescent period, which varied in length among individual females from 6 to 17 days, averaging from 7 to 10 days. Over 50 percent of the females considered exhibited two such peaks in the estrous cycle. The maximum number was three.

In the sexually mature male the testes, normally not noticeable, enlarge to the size of hazelnuts just prior to the breeding season (late June) and maintain this size until September, when a recession takes place. The penis, too, shows a gross increase in hardness and size, which according to Schmidt (1934) may be as much as five times greater than is found during the quiescent period.

Actions of the Female

During the estrous period the female frequently makes a clucking noise entirely different from that made at other times, apparently to attract the male. She squats and urinates frequently, especially on stones, fecal matter, and other objects in the pens. Seton (1926) believes that this action also is concerned with the scent glands, being a method of depositing their secretion in places where other martens are likely to travel. Both sexes were observed to rub their bellies across projecting limbs and the tops of the nest boxes. The female climbs and mounts the male when he is apparently passive. Quite often she switches her tail and wrestles with him, though squealing loudly when he treats her too roughly. When she does not accept service readily the male will chase and struggle with her until mating is accomplished. During the first week or two of the post estrous period the male may be inclined to annoy the female, as is indicated by the antagonistic attitude she assumes toward him. Such treatment soon discourages the male, however, and he discontinues further attempts to mate.

Abdominal Scent Glands

The actions referred to in the preceding paragraph suggest the presence of an abdominal scent gland in the marten. This is confirmed by the detailed observations of Hall (1926) who found the skin gland on the belly of a female marten to be one-half inch wide and three inches long. On a male a glandular area 8 mm. wide at its middle, extended from the opening of the penis anteriorly for a distance of 40 mm. On this area the longest hairs were 1.7 mm. in

length and most of them are shorter than this. In color these hairs differ from those surrounding the glandular area only in being slightly more reddish, probably the result of staining by the glandular secretion. Mr. Dixon has stated that martens which he observed, both captive and in the wild, were seen to drag their bellies over logs or limbs. These glands are known to be present in both sexes of at least three subspecies of the genus *Martes*.

Copulation

From observations made in 1941 copulation always takes place on the ground. One might not expect that such would be the case with an animal of arboreal habit. The male often seizes the female from the elevated nest or high upon the wire wall of the pen but is very persistent in his efforts to drag her down to the pen floor. The male restrains the female by biting the hair or skin of her neck behind the ears. There the skin is loose, affording considerable freedom of movement. The front feet of the male are placed on each side of the female in the thoracic region. The male may drag the female about on the pen floor for 30 minutes or more before coitus actually occurs. Females remain flat upon the ground. The vulva is exposed voluntarily by the female as the tail is bent upwards or to one side of the body. Throughout the mating act both sexes make purring or growling noises, the female usually being the more audible. Paired animals can separate easily but usually are not greatly disturbed by the presence of nearby human observers. Pairs which break apart suddenly because of struggling by the female or undue roughness on the part of the male, are often found together again within 5 or 10 minutes. Two and even three matings in one day between a single pair is not an unusual occurrence. Females will readily accept another male the next day. Failure to mate is often due to lack of interest by the male. This is noticeable particularly when the male has previously made successful matings on three or four successive days, or when he has been scratched or cut by an antagonistic female.

Fairly accurate notes were taken during the 1941 breeding season on the actual time of copulation. Approximately 50 percent of the 56 matings on

TABLE 3.—Duration of Copulatory Act in Marten.

Time Interval in Minutes	Number of Instances in Each Group
15-29	9
30-44	8
45-59	12
60-74	18
75 +	9
Total	56

which this information was obtained were of one hour or more duration, the longest being one and one-half hours.

Martens are most active during the transitional hours of the day from sunrise to 10 A. M., and from 3 P. M. until dark. It naturally follows that most of the matings occur during these periods. During some mornings, however, copulation was not terminated until 12 M., particularly on dark, cloudy days when the usual mid-day lethargy was not discernible.

The female may mate many times during each breeding season, as many as 18 being recorded by Schmidt (1934). In 1941 successful matings were obtained with seven of the nine adult females. The number of matings per female varied from five to ten. The following table (4) lists the female numbers and the numbers of matings for each animal.

TABLE 4.—Marten Females Mated, 1941.

Female No.	Matings observed	Female No.	Matings observed
49	8	61	7
57	10	64	5
59	9	70	6
60	9		

Polygamous Mating of Marten Males

At the beginning of the breeding season in 1941 nine adults and two subadult males were available for breeding purposes. Only five adult males proved active. These 5 males made 54 successful matings. This was determined by the presence of live sperm in the vaginal smears taken after all matings except those occurring near the end of the breeding season. The minimum number of matings per male was 7; the maximum 15. Nearly all adult males are highly polygamous. Occasionally an older male becomes frightened when placed in the pen with a female, but such actions are more characteristic of the subadult males. Observations on the matings of active males over a three year period are given in Table 5.

Sexual Maturity

There is still a question regarding the time the marten kitten reaches sexual maturity but available evidence indicates that while adult weight and size may be attained during the first summer sexual activity is not evidenced until the marten's second summer, when it is about fifteen months old. Bassett (1937) on several occasions examined male marten kittens during their first summer and observed a lack of development of the scrotum and testes.

Although adult males have been placed with female kittens on many occa-

sions there has not been evidence of a single mating occurring during the first summer of the female's life.

There is, however, ample evidence of sexual activity on the part of both male and female martens between one and two years of age. These data are presented in Tables 6 and 7.

TABLE 5.—Polygamous Mating of Marten Males.

	Number of Matings Observed		
Male No.	1939	1940	1941
40	3 (1)	1 (1)	0
50	2 (2)	7*(6)	..
51	5 (4)	7 (6)	15 (7)
62	12 (6)	3 (3)	9 (5)
69	5 (3)	10 (7)	11 (6)
71	0	2 (2)	7 (4)
72	0	6 (6)	12 (6)

Figures in parentheses indicate number of different females mated.
* Died, May 17, 1941.

While the above evidence is not absolutely conclusive it is believed enough is presented to show that among martens mating does not occur until the female is over a year old (about 15 months), and in over 50 percent of the cases not until the age of two to three years is reached.

It has been shown by the observations of Schmidt (1934) that year old animals, thus about 15 months old, at the rut time, very frequently show no pairing desire. Of about 150 young animals of this age scarcely 20 percent (mostly females and only five males) proceeded to mate.

While 7 of the 15 females listed in Table 6 were mated when they were about fifteen months old no young were whelped the following spring. The youngest marten mother in the history of the station was three years old when her first litter was born.

Among the 20 litters born at the Saratoga Springs station 10 came from females that were captured in the wild, so it is not possible to state the age at which their litters were born. Some of these females were pregnant when captured in the fall and gave birth to litters the following April. The remaining ten litters were whelped by females three (1), four (2), five (3), six (2), seven (1), and nine (1) years of age.

Concerning the males it may be said that while they have in many instances attempted matings between one and two years of age the youngest sexually mature marten was three years old when his first litter was sired.

It would thus appear that the marten differs greatly in its breeding habits from many of the other members of the weasel family in that sexual maturity

TABLE 6.—Breeding Data and Breeding Ages of Female Marten Kittens.

Female No.	Date of Birth	Mating Dates** Second Summer	Age when first mating was observed
15	April 16, 1922	8/16, 8/16—1923	Between 1 and 2 years
16	April 16, 1922	7/25, 7/28, 8/2, 8/16, 8/9, 8/17*—1923	Between 1 and 2 years
28	April 6, 1927	None	Between 2 and 3 years
42	April 24, 1931	7/23 8/22—1932	Between 1 and 2 years
44	April 27, 1931	8/16—1932	Between 1 and 2 years
45	April 27, 1931	None	Between 2 and 3 years
49	April 18, 1932	None	Between 2 and 3 years
52	April 21, 1932	7/25, 8/1—1933	Between 1 and 2 years
53	April 21, 1932	None	Between 2 and 3 years
57	April 7, 1934	None	Between 2 and 3 years
59	April 13, 1935	7/21, 7/22, 7/30—1936	Between 1 and 2 years
60	April 13, 1935	7/28, 8/5—1936	Between 1 and 2 years
61	April 13, 1935	None	Between 2 and 3 years
64	April 16, 1936	None	Between 2 and 3 years
70	April 15, 1938	None	Between 2 and 3 years

*Evidenced estrum, although no matings observed.
** Earlier data used "wet neck" as evidence of mating.

TABLE 7.—Breeding Data and Breeding Ages of Male Marten Kittens.

Male No.	Date of Birth	Dates mating observed	Date Litter was born	Age of male when 1st litter was sired
29M	April 6, 1927	7/20, 21, 22—1929	April 15, 1930	3 years
43M	April 24, 1931	7/18, 19, 20, 31, 8/1—1934	April 3, 1935	4 years
50M	April 18, 1932	7/29, 8/10, 11, 12—1935	April 10, 1936	4 years

is attained at a later age, and, as is to be expected, the longevity of the species is greater.

Development of Young

The series of weight gains given in Table 9 serves to illustrate the fact that physical growth in the marten is nearly complete when the kits are three months old. Reports of observations in Canada by Brassard and Bernard (1939) state that the weight of an adult female varies from 750 to 800 grams, and that of the male 1,100 to 1,200 grams. Such a pronounced sexual disparity in weights was not observed in adults at the New York station, the male being only slightly larger. There is a considerable overlapping of weights between the sexes. That is, the large females weigh more than the small males. Established methods of handling the animals during the gestation and lactation periods preclude the possibility of examining litters until they are well developed. Formerly no weight records were taken until after the animals were 50 days old. More recently, however, weight records taken at 25 days of age have given the following information. One litter born on April 15, 1940, had 2 male kits weighing 180 and 215 grams. The second litter, also born on April 15, 1940, contained 3 females weighing 174, 186, and 189 grams. A third litter, born on April 12, 1941, consisted of two males weighing 250 and 254 grams.

However, weights of younger specimens recorded by Brassard and Bernard (1939) indicate that at birth the weight was about 28 grams. Schmidt (1934) states that the average weight of new born young of the European species (*Martes martes* L.) was 30 grams. At weaning age, six to seven weeks, the average weights of four different litters born at Saratoga Springs (Bassett, 1937) varied from 435 to 480 grams or about one pound.

TABLE 8.—Weight Comparisons of Young Males, Martes spp.

American marten Martes americana		Siberian sable Martes zibellina		European marten Martes martes	
Age (Days)	Av. Wt. (Grams)	Age (Days)	Av. Wt. (Grams)	Age (Days)	Av. Wt. (Grams)
54–56	423	56	600	56	680
74–77	746	70	720	70	820
82–84	864	84	810	84	1,040
105	990	105	970	105	1,360

Information in Table 8 was taken from Brassard and Bernard (1939) for *Martes a. americana* (Turton) and from Schmidt (1934) for *Martes zibellina* L. and *Martes martes* L. Each series is an average weight of three males. Females are said to weigh 10 to 15 percent less. The comparison shows that a close similarity exists between our American species and the Siberian sable as far as

rapidity of growth is concerned. In Table 9 is given a series of average weights of marten litters raised at the Saratoga Springs station (Bassett, 1937). Both sexes are included in this tabulation, while those of Table 8 are concerned with males only.

TABLE 9.—Average Weights of Various Marten Litters (both sexes).*

Age of Young (Days)	Number in Litter	Average Weight (Grams)*
50	3	445
50	2	480
56	3	435
70	1	735
70	1	760
70	1	770
71	1	780
71	2	830
72	4	735
72	3	885
73	3	750
89	2	1,135
92	2	795

* Figures converted from original notes, which were in pounds.

TABLE 10.—Marten Whelping Dates, Sex, and Size of Litter.

Year	Litter Whelping Dates—Month of April													Male Kits	Female Kits	Total
	6	8	10	12	13	14	15	16	17	18	21	23	24	27			
1921							×								2	1	3
1922								×							0	3	3
1927	×														2	1	3
1929												×			1	0	1
1930							×		×						4	0	5*
1931													×	×	1	3	5*
1932										×	×				3	3	6
1934		×													1	1	2
1935					×										1	3	4
1936			×					×							2	2	4
1937						×									1	1	2
1938							×								2	1	3
1939											×				2	1	3
1940							×										
							×								3	3	6
1941				×											2	0	2
Total															27	23	52

* One kit destroyed by female before sex was determined.

Marten Litters

All births of which records are available at Saratoga Springs occurred during the month of April. Brassard and Bernard (1939) noted one birth in late March and four in April. Schmidt (1934) referring to the European species states that 93 percent of all births occurred in April. Since nest boxes

are not disturbed at the time when young are expected their presence is revealed by the high-pitched squeak of the young. Litters vary in size from one to four with an average for twenty litters of 2.6. The male:female sex ratio was 54:46. Complete information on twenty litters is found in Table 10.

In the European species Schmidt (1934) found that the litter size varied from 1 to 4. One young is very rare; 2 young not very common (none in the spruce marten); so that 3 can be taken as the average. The average litter size of all females studied over a four-year period was between 2.8-3.0.

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Age Determination and Rate of Growth in Polyodon spathula, by Means of the Growth Rings of the Otoliths and Dentary Bone*

Leverett A. Adams

In recent years, papers have appeared on various phases of the life history of Polyodon, but little has been reported on anything pertaining to their age. Stockard (1907) made a study of the habits of Polyodon in Louisiana, Mississippi, and Arkansas, while in search of information concerning their spawning habits. He failed to discover their spawning places, however. In his table of measurements, of 15 specimens from 30 to 69 inches, he mentions two specimens with eggs, one 63 inches and one 69 inches in length. Barbour (1911) described a small specimen 35 mm. in length. Danforth (1911) described a 74 mm. specimen. The smallest specimens now known were collected by Thompson (1933) near Grand Tower, Illinois, on the Mississippi River. These seven specimens were seined from a sandbar and were from 17 mm. to 20 mm. in length. Thompson (1934), in his paper on the relative growth of Polyodon, gives some very interesting tables showing the relation of the rostrum to the body in different periods, varying in total length from 17 mm. to 2159 mm.

The following study on the spoonbill cat or paddlefish (*Polyodon spathula*, Wallbaum) was undertaken in an attempt to estabish some facts about the rate of growth, sexual maturity, spawning age, and other desirable data about this very interesting fish. It was felt that most of the fish marketed in recent years were far below the spawning age. The history of the catches at well known points along the Mississippi, Ohio, and Illinois rivers indicates that because of changes in these streams or of overfishing the size of the catch is growing smaller and the size of the individual fishes caught is much less than in former years. This study is based upon about 100 paddlefish from 7.75 to 50 inches in length. The materials used were obtained through the courtesy of Doctor David H. Thompson of the Illinois Natural History Survey.

According to Thompson (1933) from data obtained at Chester, Illinois, in 1930, specimens studied fell into three well defined modes at lengths approximating 10, 27, and 48 inches and he remarks: "If these three modes represent one-, two-, and three-year old individuals, the spoonbill is, indeed, a rapidly growing fish."

This work on the study of the otoliths and sections of the dentary bone is taken up to make something of a check on other methods of age determination, particularly in Polyodon, and to test some of the conclusions.

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The two structures chosen as possibilities were (1) the otolith of the sacculus, the sacculith and (2) the dentary bone of the jaw. Both were examined for possible characteristics which could be interpreted as annual growths and used in determining age.

The Otolith of the Sacculus

The ear of Polyodon is quite large and it is comparatively easy to collect the large sacculith from the sacculus. In large specimens, the utriculith and lagenalith were collected, but they are rather small and did not lend themselves to the proposed study.

The sacculiths are obtained by making a horizontal section (frontal) across the top of the skull, thus exposing the sacculus which lies on the lateral face of the brain case. The shape of the sacculith is roughly that of a shovel, with the cuting edge ventral (Fig. 1). The dorsal region is tilted mesially at an angle of about 70°. The mesial face is convex and has a characteristic groove or sulcus which separates the dorsal from the ventral half. The sulcus which separates the dorsal from the ventral half. The sulcus may become filled with granular materials, but is always distinct. The dorsal region of the otolith is opaque, while the ventral is likely to be quite translucent. In smaller specimens the ventral edge is lobed, the lines separating the lobes being continued to the sulcus. There is a fine wrinkling of the surface showing that there is a constant deposition of materials on the otolith, mostly on the lateral side.

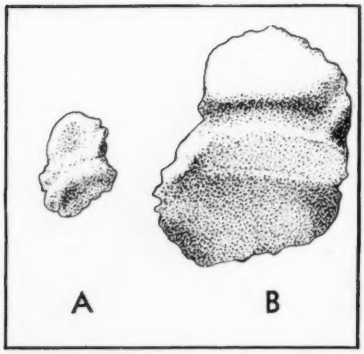


Fig. 1. A. Mesial face of otolith of specimen 7.75 inches long. B. Mesial face of specimen 21 inches long.

There are three otoliths in each ear: the lapillus in the recessus utriculi; the sagitta in the sacculus; and the asteriscus in the lagena. In another publication, I (1940) proposed different terms: utriculith for lapillus; sacculith for sagitta; and lagenalith for the asteriscus. Although the etymology is faulty, these terms are self-explanatory and useful. The otolith appears to grow differently in the dorsal and ventral regions. The dorsal region is made up of coarse granules and the material of this region is laid down in larger particles, thus making it

opaque. The groove always fills with rather coarse granules forming an opaque band or girdle around the otolith (sacculith). The ventral region is more translucent, since the materials added to this part are much finer.

In saggital section, the sacculith shows a number of laminations, constantly spaced and present in all specimens regardless of size. These laminations are always of an appreciable width and definite enough to count, but they show a gradual narrowing after the fifth or sixth ring. There is a distinct difference in the coloring of the bands; light bands alternate with darker bands which appear brownish in transmitted light but slightly milky and opaque in reflected light. The colored band appears to be a winter deposit since the second band to appear in the 7.75 inch fish is brownish. It seems probable that the difference in food habits and food material and a different winter metabolism may explain this difference in the coloration of the deposited material.

The smallest otolith (sacculith) examined, that of a fish 7.75 inches long, shows the shape and structure of the early stages very clearly. In oil of wintergreen the dorsal region (above the groove) is distinctly granular but clear and its lateral face shows only faint indications of corrugations or growth lines so characteristic of the larger specimens. The lobes of the ventral edge are distinct and have limiting sulci which converge and extend toward the groove.

The otoliths of the larger specimens differ in that they are much thicker, the dorsal half being more roughened and granular, and the ventral region

TABLE 1

Estimated age (Years)	Total Length (Standard Length)* (Inches)	Length and Width of the Sacculith (Inches)
1	7.75	0.05 × 0.03
1	12.00	0.07 × 0.06
2	18.50	0.10 × 0.07
2	21.70	0.12 × 0.09
2	24.00	0.15 × 0.11
2	24.00	0.14 × 0.09
2	24.50	0.13 × 0.09
2	24.50	0.14 × 0.10
2	25.20	0.15 × 0.10
2	25.50	0.14 × 0.10
2	25.70	0.13 × 0.10
2	25.80	0.13 × 0.10
2	27.40	0.15 × 0.09
3	28.50	0.15 × 0.09
3	30.00	0.13 × 0.10
4	33.00	0.16 × 0.12
6	39.40	0.19 × 0.14
7	40.00	0.19 × 0.11
9	44.70	0.24 × 0.13
13	50.00	0.21 × 0.16

* Standard length is the measurement from the tip of the nose to the base of the caudal fin.

having more distinct corrugations. Very little can be seen in dry material, but immersion oil is helpful only in the study of small specimens. Both frontal and saggital sections were made, but the latter were found to be much better for the determination of structure and the counting of the growth layers.

The growth of the otolith is gradual, following the growth of the fish. Table 1 shows some measurements of the otolith (sacculith in hundredths of an inch) in paddlefish of different lengths with an estimate of their age. The otoliths are measured along the mesial side for the greatest length, and the greatest width is taken at right angles to this line.

The shape of the three otoliths changes little with increased size and age, and there is but slight variation in the large series studied.

Preparation of Otoliths and Dentary Bone

The otoliths were ground on a fine carborundum stone and held on the slide by sealing wax or balsam. A saggital section was cut, the face smoothed, polished, and fixed to the slide while the grinding of the other face was completed. While rather laborious, this method was efficient. Some of the first grinding was done on an emery wheel, but the fine grinding and finishing were done on fine carborundum stones of different degrees of fineness. The final grinding has to be done very carefully, since the thin sections shatter easily. Usually sections 40 or more micra thick give the desired clearness of the layers. The completed sections are fixed to a slide with balsam in the usual way.

To test the value of the otoliths as a means of age determination, sagittal sections were made from otoliths of fish of different lengths, so that a series could be built up and studied in sequence. The material of the otoliths is laid down in concentric layers, a process which is probably going on all the time but probably varying in rate. An unknown factor connected with the seasons or the food habits possibly causes the slight color variations of the deposited layers so that definite laminations, or groups of such, are quite evident. Other fishes usually show these lines in the otoliths, and in many it is not even necessary to grind the otoliths to observe and count these layers of growth. With increased age and more rings, an exact count becomes increasingly difficult and in otoliths having more than ten rings, an estimate.

The smallest sacculiths obtained were from a fish 7.15 inches long, taken at Chester, Illinois, February 5, 1930. These otoliths measured 0.05 x 0.03 inches and their structure could be seen either in a dry state or immersed in wintergreen oil. The dorsal half is opaque and appears structureless down to the separating groove. Ventral to this groove, the otolith is translucent so that the manner of its formation could be determined. The ventral half is clear with a definite line, brownish in tinge, dividing it into two layers. From its position it is assumed that this brownish line is the winter deposit built up during the late fall and winter months. There appears to be a constant addition of material, since a series of fine lines and ridges appear

along the whole length of this cleared area. The mesial half is divided into lobes at the ventral edge, separated by shallow grooves which tend to converge at the midline of the otolith. Small, clear spherules of material are deposited along the sides. This specimen was probably hatched in the spring of 1929.

Otoliths from a 12-inch fish taken at Chester, Illinois, February 25, 1930, showed the same characters as the smaller specimens with the same clear ventral half. One otolith was studied whole by immersion in wintergreen oil, while the second was ground in saggital section. The lines were very clear and evident. Although this specimen was much larger than the other fish, it showed the same structure and the same lines. The otoliths measured 0.07 x 0.06 inches.

The smallest two year old fish was a specimen 18 inches long taken at Chester, Illinois, on the Mississippi River, in February of 1930. The otoliths measured 0.10 x 0.07 inches. These otoliths were too large and thick to be studied whole and were sectioned. The sections showed three bands, one more than the smaller fish, and it would appear that this animal was two years of age having passed its second winter. This change in the bands of the otoliths also agrees with the lines on the dentary bone. Studies were made on fish of the following lengths: 21.7, 24.00, 24.20, 25.20, 25.50, 26.80, 27.40 inches. All agreed in having the three bands and may be regarded as in their second year (Plate 1, Fig. 1).

The smallest fish of the third year class was 30 inches long and had an otolith with four growth layers. From the length frequencies of the material available, it seems that the maximum length reached in the two years is about 27 inches and this is confirmed by the ages determined by sections of the dentary bones.

Otoliths were not available for fishes between the lengths of 30 and 39 inches. One specimen with a length of 39.40 inches and a weight of 11 pounds had otoliths with seven or eight bands and an estimated age of six or seven years. A 40-inch specimen with a weight of 15 pounds had eight or nine bands and an estimated age of seven or eight years (Plate 1, Fig. 2).

A specimen with a length of 39.40 inches and a weight of 11 pounds had seven or eight bands on the sacculith and an estimated age of six or seven years. A 40-inch specimen with a weight of 15 pounds had eight or nine bands an an estimated age of seven or eight years (Plate 1, Fig. 2).

Otoliths of specimens between the lengths of 40 to 50 inches were available in the following lengths: 44.00, 44.70, 45.00, and 50.00 inches. The 44-inch fish had ten growth layers; the 45-inch fish had ten layers and an estimate of nine years; the 45-inch fish, with a weight of 15 pounds, had 13 layers and an estimated age of 12 years (Plate 1, Fig. 3).

The largest fish available was a ripe female, with a length of 50.50 inches and a weight of 25 pounds. But one specimen of this size could be obtained. In a fish of this size the growth layers become confused after about the tenth

layer, are very close together and difficult to define. The layers were fairly distinct up to the tenth, and the remaining area had to be estimated. This large specimen was probably in its thirteenth or fourteenth year. When a length of about 40 to 50 inches is reached, growth apparently slows down and there is more increase in weight. In the series examined, the smallest spawning fish, had a length of 42.50 inches and a weight of 19.7 pounds. Stockard (1907) mentioned two females, 63 and 69 inches long and ripe with eggs. More data on the spawning age is placed in the section dealing with the dentary bone of the mandible.

The Dentary Bone

The series used in this study of the dentary bones consisted of about one hundred specimens varying from 7.75 to 50.00 inches in length. They were from the same source as the material used in the study of otoliths.

A preliminary investigation was made of several bones of the skull and jaw to see if any offered growth layers distinct enough for age determination, but the others were too thin to be of any value. Te dentary, with its appreciable width, offered the most promise, so the work was centered entirely on cross sections of this bone. The sections were made in the straight region of the dentary extending back to the articulation with the quadrate. The only preparation consisted of removing the mandibles and preserving them in alcohol until used. The dentary appears to be quite regular in growth with little replacement of materials, since the peculiarities of the first bony growth remain and can be identified in mandibles of any age. The added layers vary in color, so that cross sections show alternate light and dark bands, the dark bands being brownish in transmitted light and milky in reflected light. The layers of growth, proportionately thicker in young and fast growing animals, become narrower after about the fourth year. These bands in the ground sections are very clear and easily distinguished in the younger specimens, but, as in the otoliths, become progressively difficult to determine with each added year of age.

The dentary in cross section is a tri-radiate structure with a single dorsal limb and two ventral limbs, a mesial and a lateral. The interior structure of the dorsal limb is rather confused because of the numerous blood vessels in this part of the bone and, for this reason, it is not suitable for counting the growth layers. Both the lateral and the mesial limbs can be used, the mesial being preferred because of its greater width.

Approximately 400 sections were made of the dentary bone, not only in the regions selected, but also in other parts of the mandible. Sections were cut with a jeweller's saw and ground to a proper thickness on a carborundum stone, followed by finer polishing stones. They were fixed to the slide by balsam. Either balsam or sealing wax were used to hold the section on the glass while grinding and both worked efficiently. Sealing wax was especially useful in holding the larger sections, for it hardened quickly, so that grinding could follow as soon as the sections were fixed to the slides. Because of the greater thickness of the dentary at the point where it bends mesially, sections

were made of this portion to provide the widest area for counting growth rings. Some stains were tried, but it was found that they added little to the definition of the layers. The sections were dehydrated, placed on slides with balsam when completed, and covered with a cover glass. The grinding had to be quite exact since sections too thin cleared in the balsam so that no layers could be seen. The sections had to be watched very carefully and ground until the growth layers were distinct and well defined. Most of the finished slides varied from 30 to 40 micra thick.

The smaller jaws were decalcified in hydrochloric acid and stained with Weigert's stain. The first stages of growth of the dentary are clearly shown in the 7.75 inch specimen, since the membranes and the bone are very distinct. Teeth are present until the fish have reached a length of about 20 inches when they become endentulous. The primary layer of bone is clear cut and remains so throughout the life of the animal. The dorsal limb has a number of small foramina that remain prominent. The second layer of material added is rather thin in the dorsal region but quite distinct in both of the lower limbs. The end of the original layer in the lateral limb is rather abrupt, and the new growth forms a bulb-like sheath around it (Plate 3, Fig. 8). These small specimens show very clearly the different layers of bone indicating a change of some sort in their deposition. A second specimen of the one year group, a 12-inch fish, showed the same picture and is probably of the same age. While the limits of growth of the first year could not be determined exactly, it seems probable that fish one year old may reach a length of approximately 15 inches. The range of weights is 0.11 pounds for the 7.75 specimens and 0.22 pounds in a 12-inch animal.

The fish of the second year class (Plate 2, Fig. 4, Plate 3, Fig. 9) vary between 18 and 27 inches in length. These appear to be the limits for the two year age. Sections were examined from fish of the following lengths: 18, 21, 24, 25, 26, and 27 inches, and all seemed to fall within the second year, with two additional layers of growth in addition to the original structures. The weight of this group varies from 2.00 to 4.20 pounds. Fish of the third year (Plate 2, Fig. 5, Plate 3, Fig. 10) appeared to be slowing down. This is evident after a length of 30 inches is reached. The lengths of the three year fish varied from 28 to 32 inches. Specimens 29, 30, 31, and 32 inches long were sectioned and studied. This group varied in weight from 3.60 to 5.20 pounds. Of the fifth year class, but one fish was available—a male 37 inches long and weighing 7.50 pounds (Plate 3, Fig. 12).

A single specimen of 38 inches long and weighing over eight pounds was assumed to be in its sixth year. Seven specimens varying in length from 39 to 41 inches were in either the seventh or eighth years and varied in weight from 11.00 to 15.20 pounds.

Two specimens, with lengths of 44 inches and weights of 15.30 and 16.50 pounds, were estimated to be about ten years old (Plate 2, Fig. 6). One large female, 47 inches in length with a weight of 23 pounds, was estimated at 12 years of age.

The largest fish studied was a female 50.50 inches in length and weighing 25 pounds. This spawning female was estimated to be about 13 or 14 years old. The table following shows total lengths, weights, number of growth layers, and the estimated age of a number of specimens in the different length groups. (Plate 2, Fig. 7).

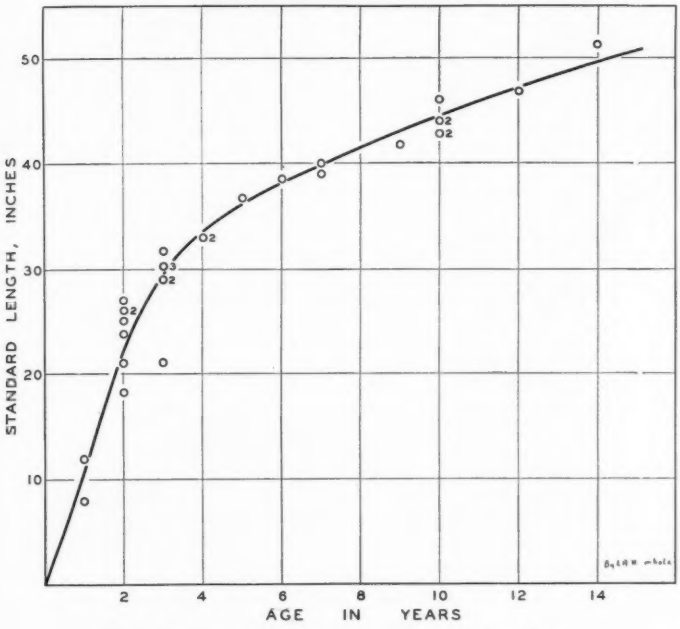
TABLE 2.—Table of Weights, Lengths, and Ages Estimated from Otoliths and Sections of the Dentary.

Total Length (Standard Length)*	Weight	No. of Layers of Growth in Otoliths and Dentaries	Estimated Age
(Inches)	(Pounds)		(Years)
7.75	0.12	2	1
12.00	0.22	2	1
21.00		3	2
21.00	2.00	3	2
21.00	2.10	3	2
24.00	4.20	3	2
25.00	2.40	3	2
25.00	4.00	3	2
26.00	2.50	3	2
27.00	3.60	3	2
29.00	5.00	4	3
29.00	5.20	4	3
30.00	3.60	4	3
30.00	4.40	4	3
30.00	5.00	4	3
32.00		4	3
33.00	7.00	5	4
33.00	7.00	5	4
37.00	7.30	6	5
38.00		7	6
39.00	11.00	8	7
39.00	11.30	8	7
39.00	11.50		
39.00	15.00		
40.00	13.80	8	7
41.00	15.20		
42.00	19.70	10	9
43.00	13.50	11	10
43.00	16.20	11	10
44.00	15.30	11	10
45.00	22.00		
46.00	16.00	11	10
47.00	23.00	13	12
50.50	25.00	14–15	13–14
74.00	150.00	(From Lake Tippecanoe, Indiana, Forbes and Richardson)	
74.00	163.00	(From Lake Manitou, Indiana, Forbes and Richardson)	
85.75		(From Lake Okobogi, Iowa, J. T. Nichols)	

* See Table 1 for definition.

Rate of Growth

Since Polyodon is commercially important and occupies a very interesting scientific position as one of the few surviving primitive fishes, information concerning both aspects will aid in its protection. Successful protection will depend on adequate knowledge of its rate of growth, of its age at maturity and reproduction, and of its spawning habits.



Curve showing relation between length and estimated age.

The rate of growth (Fig. 2, growth curve) appears to be rapid during the first three years since the fish attain a length of possibly 15 inches in the first 12 months of life, 15 to 27 inches in the second year, and 27 to 32 inches in the third year. The increase in weight is not proportionate to the length, since the approximate weight of a fish 32 inches in length is but 6.50 pounds. Most of the length comes in the prolongation of the *snout* and *tail regions*, the body remaining light in weight and rather small in girth. Specimens examined in the 40-inch length were in their seventh or eighth year indicating that growth from 32 to 40 inches and increase in weight from 6.50 to an average of about 13.70 pounds required about four years. Specimens seven to about 14 years in age ranged from 40 to 50 inches in length with an increase in weight from

13 to 25 pounds. Jordan mentions two specimens from Indiana: one from Lake Manitou with a weight of 163 pounds; and one from Lake Tippecanoe which had a length of 74 inches and a weight of about 150 pounds (Forbes and Richardson, 1920). Nichols (1916) mentions a large specimen taken with a spear in Lake Okobogi, in northern Iowa, that had a length of 85.0 inches and a girth of 45.5 inches (Fig. 2, growth curve).

Sexual Reproduction and Maturity

The question as to when the species become sexually mature is very important, both from the practical and from the theoretical point of view, especially in regions where there is commercial fishing. There has been a severe drain on the species in places where fishing has gone on continuously, and the fishermen always report that there has been a gradual reduction in the

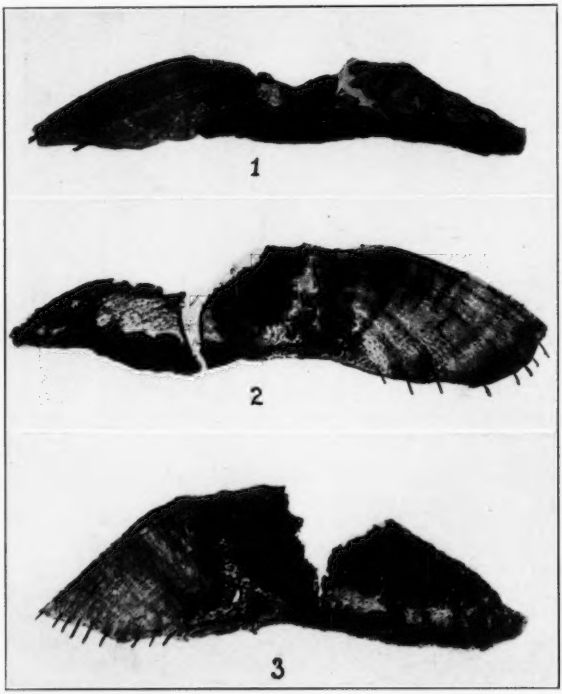


PLATE 1. Photomigraphs of Sections of Otoliths. 1. Saggital section of a 21-inch fish. Three layers. Two years old. 2. Saggital section of otolith of a 40-inch fish (172). Nine bands. Eight years old. 3. Sagittal section of otolith of a 44-inch fish (No. 18). Ten bands. Nine years old.

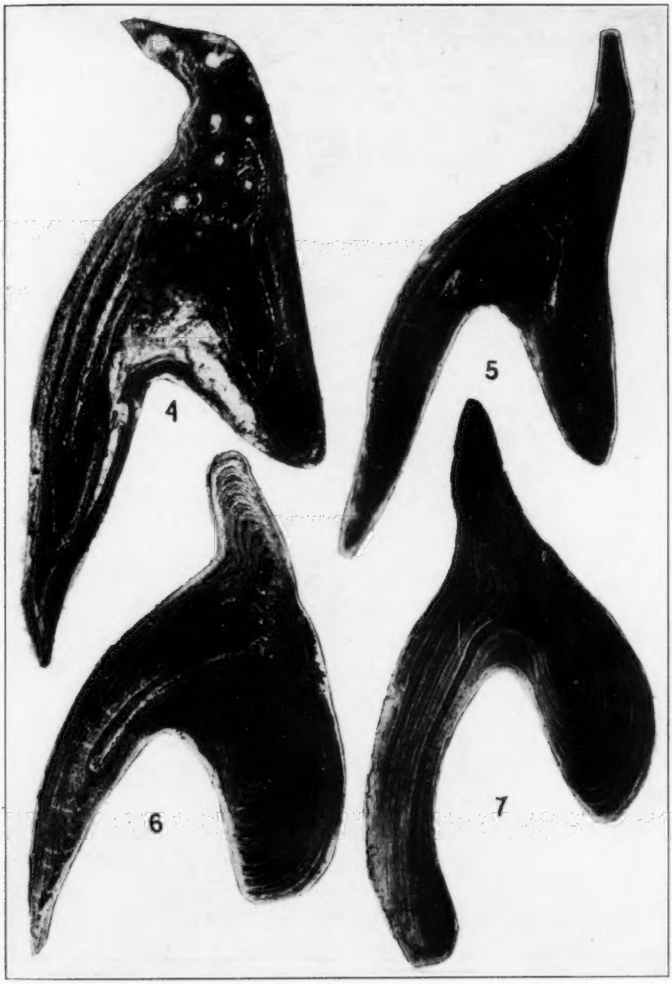


PLATE 2. Photomicrographs of transverse sections of Dentary. 4. Transverse section of dentary of a 21-inch fish. Three bands. Two years old. 5. Transverse section of a dentary of a 30-inch fish. Four bands. Three years old. 6. Transverse section of dentary of a 44-inch fish (No. 12). Ten to eleven bands. Nine to ten years old. 7. Transverse section of dentary of a 50.50-inch fish. 14 to 15 bands. 13 to 14 years old.

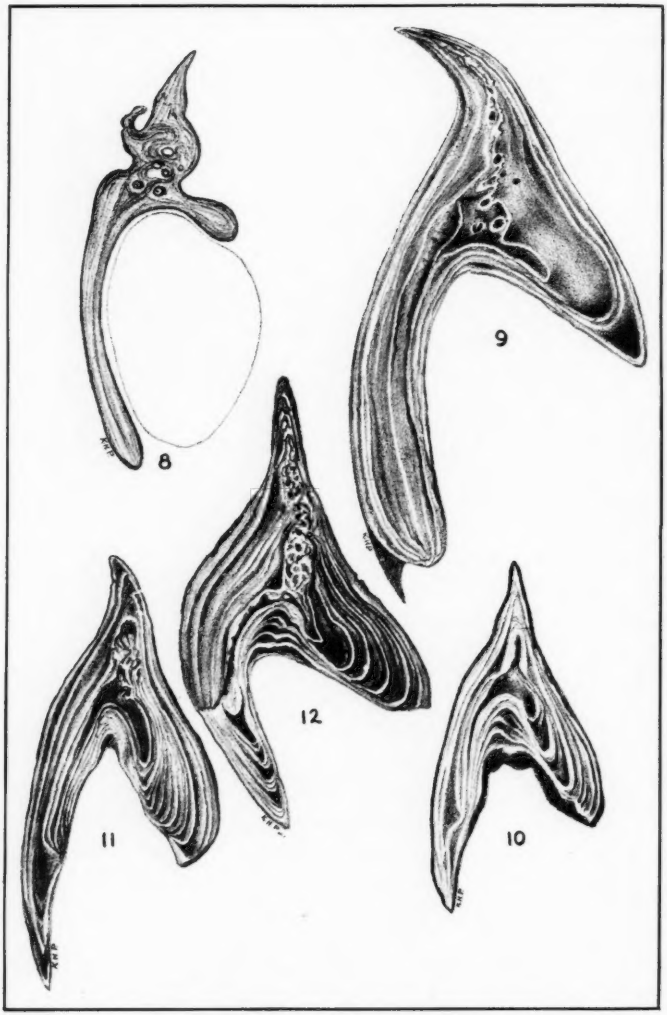


PLATE 3. Camera Lucida Drawings of Transverse Sections of Dentary. 8. Transverse section of dentary of a fish 7.75 inches in length. Age slightly less than one year. 9. Transverse section of dentary of a fish 21.7 inches in length. Age two years. 10. Transverse section of dentary of a fish 30 inches in length. Age three years. 11. Transverse section of dentary of a fish 33 inches in length. Age four years. 12. Transverse section of dentary of a fish 37.3 inches in length. Age five to six years.

size of the fish taken as well as in the total numbers. This would indicate that the breeders are being caught, and that the small forms are those that drift in from other than the immediate vicinity or from some place where the breeders have been undisturbed. From reports available, this reduction in size seems to be the regular condition wherever there is steady fishing for this species. At Meredosia, Illinois, where they were trapped as they left the bay, the same condition is true, with a reduction in both size and numbers until finally they have almost disappeared from this once favorite spot. Fishermen at Havana, Illinois, reported the same story of the glories of ancient days when the catches were large and numerous.

Although the series is not as complete as desirable, the spawning fish recorded were all large—the smallest weighing 19.70 pounds. The fish had a length of 42 inches and an estimated age of eight or nine years. Many females between 30 and 42 inches in length were handled but none were found with eggs. In my opinion, eggs are not laid until the fish reaches a length of 40 inches or an age of about seven or eight years. This makes the fish a late breeder and if the larger fishes are caught continually, there is certain to be a reduction of the breeding stock. This seems to be the condition in many places where there has been much fishing for this species and where a market has been developed for it as "boneless cat."

There is a large gap in the history of the reproduction of this species since there is but scant knowledge of the places in whihch the eggs are laid. The most important record is that of D. H. Thompson (1933) at Grand Tower, Illinois, on the Mississippi River.

Resume

1. There is a correlation between the measurements of the otoliths of Polyodon and the size of the fish. Laminations in the otoliths are built up with increasing years of age. The laminations differ in color, having a clear area and a brownish area which is milky in reflected light. These layers are clearly distinguished in the younger stages but become increasingly difficult to count after the sixth or seventh ring when the laminations become narrower and more crowded.

2. The growth of the mandible of Polyodon is a regular process of bone deposition that continues throughout life.

3. There is little or no replacement of the bone and the original material is retained, so that the structures peculiar to the first year remain little changed even in old specimens.

4. Seasonal deposits of bone vary in color, alternating light and dark, so that it is possible to estimate the age of the animal by counting the layers of growth. Two of these bands are developed in the first 12 months of the fish, and a break or change of texture marks the winter season.

5. From the material studied, it appears that the fish reaches a maximum

of 15 inches in its first 12 months, 27 in its second year, 32 in its third, and requires three or four years to extend the length ffrom 32 to 40 inches so that a fish of 40 inches is about seven years old. It requires from 13 to 14 years to reach a length of 50 inches and a weight of 25 pounds. Fish with a length of 74 inches must be considerably over 20 years of age.

6. The fish are late in maturing since they must attain a length of about 42 inches before the spawning age is reached. A fish of this size and weight would be about nine or ten years old. No data were secured on the size of mature males.

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Offatts Bayou, a Locality with Recurrent Summer Mortality of Marine Organisms

Gordon Gunter

In July, 1939, the writer was called to Galveston to investigate the sudden mortality of marine organisms in Offats Bayou. Since then several trips have been made to the bayou, none longer than a few days. In 1939 I presented an hypothesis to explain the situation, and, since subsequent observations have tended to confirm it, the facts relating to this somewhat peculiar case seem to be worth recording.

Offats Bayou is a blind neck or inlet of water on the bay side of Galveston Island, opening into West Galveston Bay. It is shown on the United States Coast and Geodetic Survey chart No. 1282: Galveston Bay and Approaches. It is two and a half miles long and most of it is approximately half a mile wide. The mouth is constricted to less than a quarter of a mile in width and the inner third is set off from the rest of the bayou by a second constriction of about the same width. The channel at the mouth is approximately twelve feet deep, this being the shallowest part of the bayou. At the inner end of the bayou the depth is said to be forty feet in some places. The greatest depth I encountered was thirty feet, but extensive soundings were not made.

Mortality has occurred every summer since 1936, except 1940, and was unknown before. These facts were ascertained from residents of the area. I am especially indebted to Mr. J. U. Rogers, who has watched the vagaries of the bayou for several years, and who has cooperated as an observer on the spot since 1939. The only event seemingly connected with the commencing of mortality was the dredging of the inner end of Offats Bayou for dirt to be used for the west end fill of Galveston. Death of animals in the bayou was not known before that time and has recurred every summer since. Dredging of the bayou has been carried on for many years (see Hopkins 1931, p. 60). Since 1931 the thirty-foot channel at the mouth of the bayou, mentioned by Hopkins, has shoaled up considerably.

Mortality occurs very suddenly in the upper end of the bayou in midsummer. I have never been on hand at the precise time but have made observations a few days afterward. Fish, shrimp, oysters and crabs die, and the crabs have been reported to leave the water and crawl ashore. The species referred to is the common Blue Crab, *Callinectes sapidus* Rathbun, and such action is not normal for that animal. The suddenness with which mortality occurs and the fact that different phyla of animals are affected argues against epidemic disease as the cause of death and conversely indicates some kind of poisoning or chemical change in the environment.

The mortality of animals seems to be connected with local disturbances in the water known to the people along the bayou as "boils." They have been described to me by several fishermen. Areas up to thirty feet in diameter in the water boil furiously with escaping gas. The color of the water in these areas has been variously described as milky, red, and black. In the parlance of fisher-

men, milky means turbid. All observers agreed that foul odors of decay accompanied the boils. One individual said that if a box of live bait shrimp was towed through the boils the shrimp all died shortly afterwards. Boats painted with white lead, when anchored in the locality of the boils, are blackened to such an extent that, as one boatman said, "When you have scraped all the black off, you have scraped all the paint off." I examined some of the boats. The blackened area was not caused by soot or oil wastes. Presumably it was caused by hydrogen sulphide coming in contact with the white lead. The boils occur at the inner end of the bayou in the deepest portion. Later the whole upper part of the bayou is affected by the bad water. Farther down it seems that the effect is slower and less severe. In a few days the situation clears up and it may or may not occur again during the summer. I have found no indications that mortality of organisms extends more than half way to the mouth of the bayou.

Death of animals during July, 1939, was rather severe and earlier than usual. It has been observed by Mr. J. U. Rogers and others that the annual summer death of marine organisms is to be expected ordinarily during the latter part of August and early September. Mortality was almost negligible in the summer of 1940. During the first part of August of that year a small Gulf hurricane came ashore near Port Arthur and brought storm tides of three to four feet in height to Offatts Bayou. In 1941 the summer mortality occurred as usual.

The writer took salinity and temperature readings of Offatts Bayou at four stations, distributed about equally from the mouth to the inner end, at different seasons. A qualitative test for hydrogen sulphide was made at the same time with lead acetate paper. The table shows the results. In December, 1940, there were rains of cloudburst proportions in the region north of Galveston Bay. There was a drop in bay salinity. One point in the lower part of Galveston Bay had a salinity of 2.5 pro mille. At that time no fish were caught in the

TABLE 1.—The temperatures in degrees centigrade and salinity in parts per thousand are given for four stations in Offatts Bayou taken at different times of the year. Station 1 was near the mouth of the bayou and Station 4 was at the inner end. The other two were equally spaced between.

Date	Station	Depth in feet	Salinity		Temperature	
			Top	Bottom	Top	Bottom
Sept. 12, 1940	1	13	27.3	30.3	26.4°	26.2°
	2	19	30.5	31.0	26.7	26.7
	3	18	30.8	30.8	27.8	28.0
	4	30	30.3	30.4	27.7	27.2
Dec. 22, 1940	1		8.2	8.9		
	2		9.8	23.6	16.6	17.0
	3		12.5	23.0	16.3	16.6
	4		13.0	23.4	16.2	16.0
March 11, 1941	1		18.6	18.7	13.8	14.0
	2		21.3	21.6	14.0	14.0
	3		21.5	22.0	13.8	14.0
	4		19.0	19.1	13.9	13.8
August 25, 1941	1		24.9	27.2	30.1	30.3
	2		23.7	26.5	30.0	30.0
	3		22.0	26.7	30.2	30.3
	4		23.3	26.8	31.0	29.2

open bay but they suddenly became extremely abundant in Offatts Bayou. Pole and line fishermen in hundreds lined the banks every day for three weeks. It was surmised that the fish retreating from fresh water found a pocket of salt water, went into it and were bottled up, so to speak, by the fresh water of the bay. This is substantiated by the salinity readings taken at that time, (Table 1, December 23, 1940). Fish remained in the bayou for several weeks. The incident is mentioned here because it indicates that circulation and exchange of water between Offatts Bayou and West Galveston Bay is not extensive or rapid.

It is well known that fresh-water lakes in temperate climates become stratified and layered due to differences in specific gravity brought about by differences in temperature of the layers. The bottom layers become deficient in oxygen at certain times of the year. In marine water specific gravity differences of top and bottom waters are much more extreme because of salinity differences.

Offatts Bayou is a body of salt water with a shallow mouth and with its deepest part at the blind end. Ordinary tides on the Gulf Coast are only about one and a half feet high in the bays. The hypothesis is advanced that these tides do not effect sufficient interchange of water between the bay and the bayou, and that the heavier water settles into what amounts to a deposition bowl at the inner end. There it stagnates and collects organic materials which putrefy finally, if not at first, under anaerobic conditions during the summer. After a time the gaseous products bubble to the surface with other soluble materials and these substances poison the organisms in the upper water layers. Hydrogen sulphide is strongly indicated. The anaerobic quality of water brought to the surface may also play a part. Aeration in a calm, protected body of water is slow.

This hypothesis was advanced in 1939. The fact that the expected condition did not appear after the storm tides of 1940, which, conceivably, flushed the bayou out, tends to confirm it as does the slow interchange of bay and bayou water indicated by the salinity readings of December, 1940.

The writer expected to get positive qualitative tests for hydrogen sulphide from bottom layers in the summer of 1941, but they were negative. I have never seen a boil or obtained water from one for analysis. However, the blackening of white lead on boats is almost as specific as a test tube test.

If the recurrent bad condition of Offatts Bayou is caused by decay of organic materials, it can possibly be improved by cutting to a minimum the amount of organic materials placed in the bayou by human beings. On the other hand, if there is enough organic materials from the natural life in the bayou to create the condiiton, then probably the situation can only be improved by deepening the channel mouth to restore the better circulation, which Hopkins[1] said was present when the bayou mouth was thirty feet deep. In any event further deepening and dredging of Offatts Bayou should not be carried on except at the mouth.

1 Hopkins, A. E. 1931—Factors influencing the spawning and setting of oysters in Galveston Bay, Texas. Bull. Bur. Fisheries **47**:57-83.

GAME, FISH AND OYSTER COMMISSION,
ROCKPORT, TEXAS.

On the Crayfishes Collected from the Big South Fork of the Cumberland River in Tennessee During the Summer of 1938

Horton H. Hobbs, Jr. and C. S. Shoup

During the course of the summer work of the first stream survey party of the Tennessee Division of Game and Fish, an attempt was made to collect crayfishes from all streams examined in the watershed of the Big South Fork of the Cumberland River in the Tennessee area. So far as we have been able to ascertain, prior to 1938 the only collections of crayfish made in this drainage were those of Dr. A. E. Ortmann on August 13 and 14, 1923, at Burnside, Pulaski County, Kentucky, and on August 13, 1924, at New River, Scott County, Tennessee. At the former locality he collected *Orconectes juvenilis* and *Cambarus bartonii bartonii,* and at the latter *Cambarus extraneus* and *Cambarus bartonii bartonii.*

From June 8 to September 15, 1938, in the course of the stream survey work the junior author and J. H. Peyton collected approximately 60 crayfish from 18 stations in Morgan, Pickett, Scott, Anderson, and Campbell counties, Tennessee. Approximately 90 localities were examined on the various streams of this watershed, including a station on a tributary of Jellico Creek, Scott County, somewhat to the east of the Big South Fork drainage. The crayfish were not actively searched for, but were taken incidental to the fish collection work in progress, generally in hauls with the seine. Subsequent collecting by the same method (Shoup, Peyton and Gentry, 1941), revealing larger numbers of crayfish in other watersheds, would seem to indicate that the crayfish fauna of the Big South Fork is somewhat impoverished. It has already been pointed out (Shoup, 1940; Shoup and Peyton, 1940) that this drainage is for the most part rather barren so far as aquatic life is concerned.

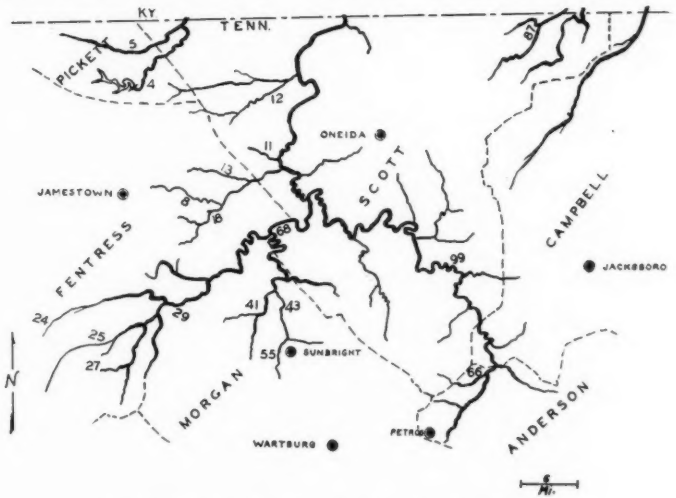
Nearly all the streams of the area flow over weathered sandstones and shales of Pennsylvanian age, with limestones almost entirely lacking except in a limited area near the Kentucky state line. Here the Big South Fork has cut its way into the Mississippian of the St. Louis-Chester-Warsaw formation, the lower parts of which contain some soluble limestones. This watershed is largely wooded, particularly in the sections west of the Big South Fork and along the main stream itself. Only limited portions of the drainage are used for agriculture, but for many years the major portions of the area have been extensively logged. Most of the streams except New River flow in deep wooded canyons with abundant cover. Adequate shelter for bottom organisms is present under large boulders and ledges of the sandstone bed of the streams. The edges of the streams are for the most part sand and weathered sandstone with little silt deposit. Pollution has apparently played am important role in the ecology of the streams in this area. For years the water in certain streams has been

either constantly or intermittently polluted by mine wastes, and such streams for the most part contain an impoverished fauna.

On the basis of our ecological data we do not feel that the aquatic situations show sufficient variation to account for the distribution of the variants of *Cambarus bartonii* except in the following instances. The variable group labeled "atypical" *bartonii* (Stations 8, 11, 18) appears to be restricted to (1) the swiftly-flowing stream tributaries of the Big South Fork in Scott and Fentress counties, and (2) an unpolluted section of a similar stream, Cage's Fork of New River (Station 66) east of Fork Mountain, Scott County. These streams are shaded and rocky and drain an area covered by second-growth timber with no agriculture to alter essentially the original nature of the watershed.

Cambarus bartonii is characteristic of those streams which are typical of the Cumberland Plateau and the edge of the Eastern Highland Rim. These streams are swift and are subject to considerable fluctuations in waterflow. We believe the fact that no crayfish were taken from New River above Norma, Scott County, may be explained by the intermittent acid coal mine pollution which occurs in upper New River at nearly all seasons.

Examination of chemical data available for these streams shows no evident correlation between alkalinity, pH. and free carbon dioxide and the distribution



WATERSHED OF THE BIG SOUTH FORK OF THE CUMBERLAND RIVER IN TENNESSEE

Fig. 1. Map: Watershed of the Big South Fork of the Cumberland River in Tennessee showing stations yielding crayfish collections, 1938.

of crayfish, except possibly in the case of *Cambarus extraneus* and *Orconectes juvenilis*. Both of these species were taken from waters somewhat higher in total (bicarbonate) alkalinity than most of the streams in this watershed. The former may have moved upstream in the Big South Fork into a few of the western tributaries, and the latter, represented in this collection from Station 87, was not found in the Big South Fork drainage. *O. juvenilis* was not obtained by Ortmann on the Cumberland Plateau in Tennessee, and was collected by us only from streams which flow in the Mississippian formations which bear larger quantities of soluble carbonates.

The result of chemical analyses of waters where crayfish were taken are shown in Table 1.

TABLE 1*

Species	Station	Methyl Orange alkalinity (p. p. m.)	pH.	Free CO_2 (p. p. m.)
C. bartonii (Typical)	99	6.0	6.5	2.0
C. bartonii (Atypical)	8	2.8	7.0	7.6
	11	15.0	7.0	4.0
	18	6.6	6.9	2.0
	66	13.3	7.0	3.0
C. bartonii Variant 5	25	17.1	7.0	7.0
	27	9.5	6.9	16.0
	29	9.5	7.0	2.0
	68	13.3	7.0	2.0
C. bartonii Variant 6	4	2.0	7.0	7.8
	5	2.3	6.9	8.4
	24	9.5	7.0	2.0
	41	16.1	7.0	8.0
	43	11.4	7.1	4.0
	55	6.6	7.0	4.0
C. extraneus	12	43.7	7.2	2.0
	13	32.3	7.1	1.0
	87	20.9	7.0	8.0
O. juvenilis	87	20.9	7.0	8.0

* Further data and methods may be obtained from Shoup (1940).

As a result of this survey several additional localities have been established for the two previously recorded species, *extraneus* and *bartonii bartonii*, and two new local stream variants of the latter were found in this watershed.

KEY TO SPECIES WHICH DO OR MAY OCCUR IN THE BIG SOUTH FORK 2

1 First pleopod of male terminating in two tapering, more or less straight processes ..... Genus *Orconectes* 2

1′ First pleopod of male terminating in two short processes bent at approximately right angles to the main shaft ..... Genus *Cambarus* 4

2(1) Margins of rostrum elevated, thickened, concave laterad; first pleopod of male reaching coxopodite of second pereiopod ..... *Orconectes rusticus* 3

2′ Margins of rostrum not thickened, almost parallel; first pleopod of male reaching coxopodite of first pereiopod ..... *Orconectes juvenilis*

3(2) Shoulder present on anterior surface of first pleopod of male, form I; and areola longer than 1/3 of carapace ..... *Orconectes rusticus rusticus*

3′ Shoulder not present on anterior surface of first pleopod of male, form I; areola also longer than 1/3 carapace ..... *Orconectes rusticus placidus*

4(1′) Rostrum without lateral spines 5

4′ Rostrum with lateral spines ..... *Cambarus extraneus*

5(4) Areola not obliterated in middle 6

5′ Areola obliterated in middle ..... *Cambarus diogenes diogenes*

6(5) Length of areola less than 40 per cent of entire length of carapace 7

6′ Length of areola 40 per cent (or more) of entire length of carapace 8

7(6) Margins of rostrum parallel and thickened, anterior ends angular, surface appearing deeply excavate ..... *Cambarus bartonii cavatus*

7′ Margins of rostrum more convergent, not thickened, anterior ends rounded, surface rather flat ..... *Cambarus bartonii bartonii*

8(6′) Inner margin of hand with sharp, distinct tubercles; carapace coarsely granulate laterally ..... *Cambarus bartonii striatus*

8′ Inner margin of hand with weak tubercles; carapace finely granulate ..... *Cambarus bartonii laevis*

COLLECTING STATIONS

Station No. Locality

2.—Beaver Dam Creek, Johnson County, eastern tip of Tennessee. (Not in Big South Fork Drainage). (*C. montanus montanus*, 1 ♀)

4.—Thompson's Creek, Pickett State Forest, Pickett County. (*C. bartonii bartonii*, Var. 6, 6 ♀ ♀)

5.—Rock Creek, Pickett State Forest, Pickett County. (*C. bartonii bartonii*, Var. 6, 1 ♂ II)[3]

8.—White Oak Creek, Fentress County. (*C. bartonii bartonii*, atypical, 1 ♂ II, 2 ♀ ♀)

11.—Bandy Creek, Scott County, tributary of the Big South Fork. (*C. bartonii bartonii*, atypical, 1 ♂ II, 2 ♀ ♀)

12.—Laurel Fork of Station Camp Creek, Scott County, western tributary of the Big South Fork. (*C. extraneus*, 1 ♂ II)

13.—Laurel Creek, tributary of White Oak Creek, Fentress County. (*C. extraneus*, 1 ♂ II)

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2 This key, modified from Ortmann (1931), will separate the more clearly marked extremes of the forms treated, but must be used with caution because of the wide range of variation within each of the species as well as the apparent intergradation between the several subspecies of *bartonii*.

3 This sign will be used to designate male, form II (♂ II); and for male, form I, the symbol (♂ I).

18.—Mill Creek, tributary of White Oak Creek, Fentress County. (*C. bartonii bartonii*, atypical, 1 ♂ II)

24.—North Prong of Clear Fork River, tributary to the Big South Fork, Fentress County. (*C. bartonii bartonii*, Var. 6, 2 ♀ ♀)

25.—Long Branch, tributary to South Prong, Clear Fork River, 1½ Miles E. of Grimsley, Fentress County. (*C. bartonii bartonii*, Var. 5, 2 ♂ ♂ imm., 5 ♀ ♀ imm.)

27.—Mill Creek, tributary of South Prong, Clear Fork River, Fentress County. (*C. bartonii bartonii*, Var. 5, 2 ♂ ♂ II, 7 ♀ ♀; Var. 6, 2 ♀ ♀)

29.—Clear Fork River at Gatewood Ford, Fentress County. (*C. bartonii bartonii*, Var. 5, 1 ♀)

41.—Boone Camp Creek, tributary of White Oak Creek which drains into Clear Fork River, Morgan County. Occasionally referred to locally as "South White Oak Creek." (*C. bartonii bartonii*, Var. 6, 1 ♂ I)

43.—White Oak Creek, Morgan County. (*C. bartonii bartonii*, Var. 6, 3 ♂ ♂ I)

55.—Pigeon Branch, tributary of White Oak Creek, Morgan County. (*C. bartonii bartonii*, Var. 6, 1 ♂ I, 1 ♂ II, 2 ♀ ♀)

66.—Cage's Creek (or "Cage's Fork"), tributary of New River, Anderson County. (*C. bartonii bartonii*, atypical, 1 ♂ II)

68.—White Oak Creek at junction with Clear Fork River, Scott County. (*C. bartonii bartonii*, Var. 5, 1 ♂ I)

87.—Gum Fork, tributary of Jellico Creek, Scott County, E. of the Big South Fork Watershed. (*O. juvenilis*, 1 ♂ I; *C. extraneus*, 1 ♀)

99.—New River at Norma, Scott County, below a section of stream subjected to acid coal mine pollution. (*C. bartonii bartonii*, atypical, 1 ♂ I, 2 ♀ ♀, 2 ♀ ♀ imm.)

Annotated List

ORCONECTES JUVENILIS (Hagen)[4]

Represented from Station No. 87

So far as we know, only one member of the genus *Orconectes* inhabits the Big South Fork Watershed [Ortmann (1931: 86); 2 males, form II, and 1 female of *Orconectes juvenilis* were taken from a "Run tributary to South Fork Cumberland River, Burnside, Pulaski County, Kentucky"]; and on this reconnaisance collection only a single specimen (a male, form I) was obtained from Station 87, a tributary of Jellico Creek outside the Big South Fork drainage in Campbell County, Tennessee. This stream is quite near the Tennessee-Kentucky state line, flowing at about 1200 feet altitude in the Pennsylvanian formation known as the "Jellico-Briceville," characterized by interbedded sandstones, sandy shales, argillaceous shales, and scattered coal beds. The total alkalinity (bicarbonate) of this stream is somewhat above the average for the Big South Fork drainage.

Distribution: "The metropolis of this species is in the rivers of Kentucky, Licking, Kentucky, Green, and upper Cumberland. It is also found in the head-

4 *Orconectes* is here substituted for the genus *Faxonius* Creaser (the subgenus *Faxonius* of other authors). The reasons for this change are pointed out in "A Generic Revision of the Cambarinae" (Amer. Midl. Nat. **28**(2):334-357, 1942), by the senior author.

waters of Big Sandy, in West Virginia, and in Clinch River in Virginia and Tennessee. These localities are grouped around the highest parts of the Cumberland Mountains, and the adjoining portion of the Cumberland Plateau." (Ortmann, 1931: 87).

CAMBARUS EXTRANEUS Hagen

Represented from Stations Nos. 12, 13, 87

Ortmann (1931: 97, 102, 104) records *Cambarus extraneus* from New River, Scott County, Tennessee (2 males, form II, 4 females).

In the present survey three additional localities have been discovered; a male, form II, was taken from Laurel Fork, a "rugged" tributary of Station Camp Creek, buried deep in the wooded canyons of the western side of the Big South Fork in Scott County, Tennessee; another male, form II, was collected from Laurel Creek, a very inaccessible tributary of White Oak Creek in Fentress County, Tennessee; and a female was found in Jellico Creek, Scott County, in the "Jellico-Briceville" formation, as noted under *O. juvenilis*. *C. extraneus* appears to us to be a species largely confined to the headwaters and small tributaries which have abundant shade and cover, and in streams completely free from the effects of soil erosion. In our collections the few specimens were taken between Jamestown and the Big South Fork, (except the specimen from Jellico Creek which is outside the Big South Fork Watershed) and above the site of acid coal-mine pollution and coal washing. Jellico Creek joins the Cumberland River in Whitley County, Kentucky, upstream from where the Big South Fork empties into the latter.

Our three specimens agree with Ortmann's *second group* (Ortmann 1931: 102) and seem to be more similar to his Livingston and New River specimens, with the very long fingers of the latter (1: 2.1). The species has been found in the Cumberland, Tennessee, and Alabama drainage systems (Ortmann 1931: 97-98).

CAMBARUS BARTONII BARTONII (Fab.)

This species has been recorded from two localities in the Big South Fork. (3 males, form II, and 1 female were taken from Hay's Branch, Burnside, Pulaski County, Kentucky, and 4 males, form II, and 2 females from New River, Scott County, Tennessee). Ortmann 1931: 132.

Ortmann (ibid: 136) recognized the peculiarities of the *bartonii* collected from New River and designated these specimens *regionally restricted form 2* and characterized them as follows: ".... rostrum is somewhat narrow and more tapering . . ., and the row of tubercles on the inner margin of the palm is quite distinct and sharp, with traces of a second row next to it. The rest, chiefly in the long areola, with three or four rows of irregular dots, are *bartonii*."

None of our specimens fits this description perfectly, and there are two

stream variants[5] which seem to fit more of Ortmann's *regionally restricted variants*. These variants are herein designated 5 and 6.

Regionally Restricted Variant 5 (Plate 1, Figs. 5 and 8)—This variant is similar in most respects to typical *bartonii*, but the chelae are more *striatus*-like. There is a row of sharp tubercles along the inner margin of the palm, subtended by a weak row above, and a distinct ridge is present on the upper surface of each finger and along the outer margin of the hand. The whole hand is broad and somewhat triangular. There is a marked increase in width of the immovable finger near its base (See Plate 1, Fig. 8). The rostra of the specimens from Station 27 are almost identical with those of typical *bartonii* from eastern Pennsylvania. There are no lateral spines on the carapace. The length of the areola is 33.0-39.7 per cent of the width of the carapace, (Average 35.38 per cent).

In the specimen from Station 29 the acumen is not so abruptly set off, and in specimens from Station 25 the rostrum is still more tapering. However, the chelae of specimens from all of these localities are very similar. The single large first form male from Station 68 has a broad rostrum with a very small acumen. The one chela is deformed.

This Variant (5) was collected at stations 25, 27, 29, and 68, all in the drainage of the Clear Fork River, the principal western tributary of the Big South Fork. The stream is characterized by a low total alkalinity averaging only 10.8 parts per million from 9 stations where methyl orange tests were made. The water flows over bed rock and rubble of siliceous nature; there is good shade and excellent cover under rock ledges and in crevices. Aquatic vegetation is extremely limited, and there is a paucity of bottom fauna. The Clear Fork

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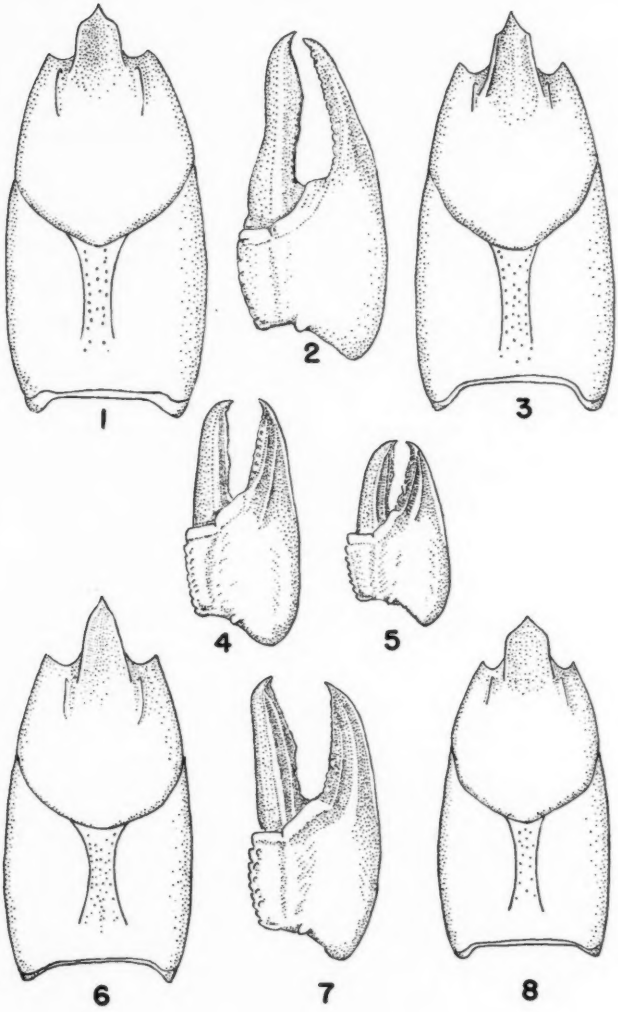
[5] Since the term "form" already is used in a technical sense among crayfish workers, we here use the term "variant" instead of "form"; hence, "*regionally restricted variants*" 1, 2, 3, 4 = Ortmann's "*regionally restricted forms*" 1, 2, 3, 4, respectively.

PLATE 1: Fig. 1—Dorsal view of carapace of *Cambarus bartonii bartonii* from Chester County, Pennsylvania. Fig. 2—Right chela of *Cambarus bartonii bartonii* from Chester County, Pennsylvania. Fig. 3—Dorsal view of carapace of *Cambarus bartonii bartonii* from New River, Norma, Scott County, Tennessee. (Station 99). Fig. 4—Right chela of *Cambarus bartonii bartonii* from New River, Norma, Scott County, Tennessee. (Station 99). Fig. 5—Right chela of *Cambarus bartonii bartonii* (variant 5) from Mill Creek, Fentress County, Tennessee. (Station 27). Fig. 6—Dorsal view of carapace of *Cambarus bartonii bartonii* (variant 6) from White Oak Creek, Morgan County, Tennessee. (Station 43). Fig. 7—Right chela of *Cambarus bartonii bartonii* (variant 6) from White Oak Creek, Morgan County, Tennessee. (Station 43). Fig. 8—Dorsal view of carapace of *Cambarus bartonii bartonii* (variant 5) from Mill Creek, Fentress County, Tennessee. (Station 27).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River is considered by us a typical upper Cumberland Plateau stream which flows over weathered sandstone through an extremely unproductive agricultural area.

Regionally Restricted Variant 6 (Plate 1, Figs. 6 and 7).—The rostrum is narrow and tapering with a long acumen; the chelae have long fingers; the inner margin of the palm has a row of well-defined tubercles subtended by a less well defined row above. Lateral spines are almost always present on the carapace. The length of areola is 33.7-36.6 per cent of the length of carapace, (Average, 35.36 per cent).

This Variant (6) has been found in several western tributaries of the Big South Fork. (Our stations 4, 5, 24, 41, 43, and 55.) Stations 41 and 43 are on White Oak Creek in Morgan County in a section of the stream which for years has been intermittently polluted by crude oil from a small refinery.

The rest of our *bartonii* specimens collected in this drainage show so many individual traits that they cannot be referred to any of the 6 variants. Our series from any one locality is small, and additional and more intensive collecting should be done.

A small male, form II, was taken from Cage's Fork (Station 66), a small tributary of the New River, isolated by extreme acid coal-mine pollution in the latter. This specimen shows a distinct row of tubercles along the inner margin of the palm; however, there is no second row. The rostrum is slightly more tapering than in typical *bartonii*, and no lateral spines are present on the carapace.

A series of specimens collected from White Oak Creek (our stations 8, 11, 18) evidence some individual variation, chiefly in the width of the areola. The rostra are all similar in that they are more tapering and possess a longer acumen than does typical *bartonii*. The chelae vary considerably; however, only one or two specimens show the second row of tubercles along the inner margin of the palm, and in some instances the single row is poorly defined. In the older specimens ridges on the fingers and outer margin of the palm are very conspicuous, while no lateral spines are present on the carapace.

Among several specimens (Plate 1, Figs. 3 and 4) of *bartonii* taken from New River, at Norma, Scott County, Tennessee, (Station 99) some seem to agree at least in part with Ortmann's Variant 2, while at least one specimen is very near to typical *bartonii*.

As to the significance of these variants, we have insufficient data to make any concrete statements. The following statements are made only as suggestions and explanations: (1) The specimens we have labeled "atypical" *bartonii* are represented by so few individuals from each locality that this grouping is simply a reservoir for those specimens which were not referable to any of Ortmann's variants or to our variants 5 and 6; (2) Variant 5, on the other hand, possibly should bear a specific name, or it may be an eastern form of *bartonii striatus*. Until the crayfishes of the intervening area (between Nash-

ville and our region) are better known, we think it best to simply point out this variation. (3) Variant 6 appears to be a very local form of *bartonii* since its diagnostic features are seen in other specimens (however, all of them are found in no other specimen) of the "atypical" group.

We have discussed these variants and prepared diagrams of them, so that later workers on the *bartonii* group will have some idea as to the nature of this assemblage in the Big South Fork drainage.

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Observations on the Biology of the Dwarf Crawfish, Cambarellus shufeldtii (Faxon)[1]

George H. Penn, Jr.

Cambarellus shufeldtii and other small crawfishes may assume importance in southern fresh-water fisheries biology as a year-round source of small-sized forage food in hatchery ponds and small lakes. They fill all of the requirements stated by Viosca (1937) for suitable forage species, i.e., they have a long breeding season, are of non-migratory habits (as far as is known), are the inhabitants of ponds, and are primarily of vegetarian habits. Because of their small size there is little danger that they will roil the water, burrow deeply into the levees, or extensively destroy the larger vegetation, and finally, they are just large enough when adult (usually about one inch long) for fingerling bass and sunfish to feed on extensively. Viosca (1937) highly recommended the use of small species of crawfishes in fish cultural projects. It seems pertinent therefore that all observations of the biology of these species should be recorded.

C. shufeldtii is the best known of the small crawfishes, having been described by Faxon in 1884 from a collection made near New Orleans. Series of specimens collected at irregular intervals over several years at two localities in particular which are typical habitats of the species comprise the source of most of the life-history data. These localities are the swamps at Indian Village (St. Tammany Parish) and Chalmette (St. Bernard Parish), Louisiana.

A peculiar dimorphism of color pattern is found in both males and females, juvenile and adult *C. shufeldtii*. No demonstrable anatomical difference can be found between the possessors of the two color patterns, nor is there an intermediate or blending of the two. One is a spotted form, characterized by several rows of dark steel-blue spots on the dorso-lateral surfaces of the carapace and abdomen. The second is a striped form characterized by several dark steel-blue stripes alternating with pigmentless stripes of equal width running the length of the carapace and abdomen. Occasionally in restricted localities individuals have been encountered in which the stripes are brick-red instead of blue. It is easy to hypothesize how one may have developed from the other either by fusion of spots or the breaking up of a stripe, but each crawfish is distinctly marked with one or the other pattern. Here is a problem that should prove interesting to geneticists.

By grouping all of the Louisiana collections into months, data indicating the seasonal distribution of egg-laying by the females, and of the attainment

1 Partially aided by grants from the New Orleans Academy of Science and the A. A. A. S. in 1940; and, use of the Zoology Laboratory at Tulane University, New Orleans.

of first form by the males have been accumulated. Since these data are drawn from a heterogeneous lot of collections made by various collectors over a period of years, they are of value only to indicate probabilities and should not be accepted as conclusive. These data are presented in a graph (Figure 1). Apparently there is one primary season of spawning and egg-laying beginning in the fall and winter months, reaching culmination in January and February and continuing through until June. The attainment of maturity that comes with form I in the males conforms rather closely to the period of egg-laying of the females, but begins a little earlier in the fall. Unfortunately sufficiently large July, August and September collections are not available for analysis.

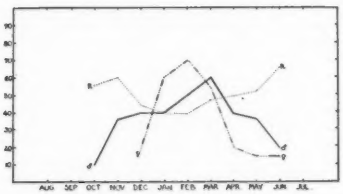

Fig. 1. Percentage of males of first form (heavy solid line ♂—♂); percentage of females with eggs or young (dot-dashed line ♀ - — ♀); and, percentage of males in total collections (dotted line R - R).

Eggs and young were removed from the swimmerets of 100 female *C. shufeldtii* collected in January 1941 in order to obtain some idea of the productivity of the species. Because the eggs and young carried on the parent's abdominal swimmerets can so easily be brushed off in the process of collecting and preserving the animals, the figures may be slightly in error. However, it has been shown in a large series of egg counts of *Cambarus clarkii* by the writer (1942) that there is a large variation even in ovarian egg production among females of the same size group, and therefore the data as gathered for *C. shufeldtii* need not necessarily be considered as erring too greatly. These data are presented in Table 1, and as would be expected vary in an orderly sequence in direct proportion to the size of the female.

The eggs are black when extruded and fastened to the swimmerets of the abdomen. Those measured were 0.9 mm. to 1.1 mm. in diameter (average 1.0 mm.).

The young crawfishes grow rapidly after hatching. In cooperation with Mr. Percy Viosca, Jr., of the Louisiana Department of Conservation, about seven hundred adult *C. shufeldtii* and three hundred *Orconectes clypeata* collected January 18, 1941, from a pine-barren pond near Pearl River, La., including about 250 ovigerous females of the former, were shipped to a state fish hatchery about 60 miles beyond the western limit of the known range of *C. shufeldtii*.[2]

2 *C. shufeldtii* has been found only east of the Mississippi and Atchafalaya Rivers; the fish hatchery is located in Rapides parish near Forest Hill, La. It may be well to note here also that about 18,000 mixed *C. shufeldtii* and *O. clypeata* from Pearl River, La. were planted in a private fish-cultural project, the Peg Factory Lake near Hamilton, Georgia on March 15, 1937. The lake is on the Blue Springs Farm owned by Cason Callaway.

TABLE 1.—Egg production of *Cambarellus shufeldtii*.

Cephalothorax Length in Mm.	Number of Eggs	Number of ♀♀	Total No. Eggs	Ave. No. Egg/♀
8.5	18 20 21 21 23 24 24 25 25 26 28 29 29 32 34 36 38 38	18	491	27
9.0	25 25 27 28 28 28 29 29 29 31 31 32 32 33 34 34 34	17	509	30
9.5	23 24 24 24 25 25 27 29 29 30 31 31 32 32 34 35 35 36 36 36 37 38 38 39 40 42 44	27	876	32
10.0	22 30 32 32 34 35 38 38 40 42 43 44 46 47 47 48 48 54 57	19	677	36
10.5	23 32 36 39 39 42 44 45 47 50 52 53 54	14	556	39
11.0	38 49 49 70	4	206	54
11.5	60	1	60	60
Total		100	3375	33.7

The hatchery pond supported a healthy growth of aquatic vegetation on a mud bottom and no game fish were present. About sixty days later thousands of adult *C. shufeldtii* and no *O. clypeata* were reported as seined from the vegetation; about one-fourth of the *C. shufeldtii* were reported as ovigerous females. These gravid females captured after 60 days were undoubtedly the young (embryonic) or egg stages when introduced into the pond, and in addition some were probably of the original adult stock. In other words there was an increase in the population of adult ♀♀ and it is obvious that most of them (since they were in very large numbers) were the result of increase after introduction into the new pond. These observations although very crude serve to point out the possibilities that may be developed from further study of this species at fish hatcheries.

A few data of the sex ratio during the year are also presented in Figure 1. Because of their incompleteness no significance can be attached to the season variation indicated.

Apparently *C. shufeldtii* has a wide range of ecological tolerance. Collections have been made in a number of diverse situations, but especially prominent among these are the swamps of the alluvial lands in the old delta region of the Mississippi River near New Orleans, and in the pineland ponds and sloughs of the Florida parishes of Louisiana. These ponds are usually characterized by shallow water, absence of fishes, and luxuriant growths of either the

flat-stemmed rush, *Juncus repens,* or the midget spikerush, *Eleocharis acicularis* (?), or both. The pH of waters in which ovigerous females were found ranged from 5.4 to 7.4.

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Glyptometopa Ashmead and Related Genera in the Brachycistidinae, with Descriptions of New Genera and Species (Hymenoptera, Tiphiidae)

Clarence E. Mickel[1] and Karl V. Krombein[2]

A year or two ago two specimens of wingless female wasps referable to *Glyptometopa* Ashmead came to the notice of the senior author. The large size (lengths 10 mm. and 12 mm.), general habitus, and brown color of these two specimens immediately suggested certain males of the genus *Brachycistis* Fox. After considerable study and comparison of these two females with numerous specimens of *Brachycistis* males the conclusion was reached that *Glyptometopa* Ashmead and its relatives represented the female sex of *Brachycistis* Fox. Only five specimens of *Glyptometopa sensu lato* were available to the senior author, and the problem was put aside temporarily in the hope that an opportunity might present itself to secure additional specimens and especially to make field observations confirming the above conclusion.

The junior author had previously[3] shown that the females formerly associated with *Brachycistis* Fox by Fox[4] and Bradley[5] were incorrectly placed and that they were actually females of *Myrmosa (Myrmosula)*. This action left *Brachycistis* without any described representative of the female sex and led him to review the described Nearctic scolioid genera known only from the female sex in order to determine whether one of them might be associated with *Brachycistis*. The result of this review was a conviction that *Glyptometopa* Ashmead had the requisite characteristics for the female sex of *Brachycistis*.

Correspondence between the authors of this paper revealed that each had reached the same conclusion independently by different methods of approach, and it was agreed to pool our specimens and collaborate in the writing of this paper.

The brief for the case of *Glyptometopa* is as follows: *Typhoctes* Ashmead[6] (originally proposed in the Myrmosidae) and *Glyptometopa* Ashmead[7] (originally proposed in the Thynnidae) are the only known Nearctic scolioid genera limited to the female sex which have not been associated with some

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1 Paper No. 1964, Scientific Journal Series, Minnesota Agricultural Experiment Station.

2 Part VI of the junior author's series entitled "Studies in the Tiphiidae."

3 Krombein, K. V., Trans. Amer. Ent. Soc., lxv, pp. 456 *et seq.* (1940).

4 Fox, W. J., Trans. Amer. Ent. Sov., xxv, p. 285 (1899).

5 Bradley, J. C., Trans. Amer. Ent. Soc., xliii, pp. 280-281 (1917).

6 Ashmead, W. H., Journ. N. Y. Ent. Soc., vii, p. 53 (1899).

7 Ashmead(W. H., Psyche, viii, p. 251 (1898).

group of scolioid males. Bradley[5], following Ashmead[6], associated *Agama attenuatus* Blake, known only from the male sex, with *Typhoctes*. Buzicky[8] has shown that *attenuatus* belongs in *Chyphotes* Blake, a conclusion with which both of us are in agreement. This leaves *Typhoctes* without any associated males.

Malloch[9] declares that *Typhoctes* is the female of *Brachycistis*, basing his conclusion on the similarity of the oblique pleural suture in the two and the similarity in form of the first abdominal segment in *Typhoctes* and in the more robust *Brachycistis* males. He admits that the formula of the tibial calcaria is different for the two and that the *Typhoctes* female bears a lateral longitudinal stripe of short, dense hairs (*i. e.*, a "felt" line) on the second tergum, which is absent in all *Brachycistis* males. We think that the formula of the tibial calcaria may not be of too great importance and that any difference may be due to a sex-limited character—for instance, the formula of the male of *Methoca* Latreille is the normal 1-2-2, whereas in the female it is 1-1-1. Malloch's reference to the "oblique pleural suture" of *Typhoctes* and its similarity to the same suture in *Brachycistis* is actually a comparison of the mesopleural-metapleural suture of both; it is not a pleural suture in the sense of a suture between the episternum and epimeron of the same segment. Furthermore, the thorax of wingless hymenopterous females, such as those of *Typhoctes*, has been so modified by the loss of wings and by fusion of the thoracic segments, that there is not likely to be any great significance in the relative obliquity of the mesopleural-metapleural suture in the two sexes. A somewhat similar view is expressed in a recent paper by J. A. Reid[10] on the thorax of wingless Hymenoptera. Furthermore, the shape of the first abdominal segment is of no more than specific or subgeneric importance in *Brachycistis*, since it varies from very distinctly petiolate anteriorly and nodose posteriorly to more or less nonpetiolate anteriorly and sessile posteriorly with the second segment.

The presence in *Typhoctes* of a "felt" line laterally on the second abdominal segment and its absence in *Brachycistis* seems to us to be a fundamental obstacle in associating these two genera as opposite sexes. This character, the "felt" line, appears to be of family rank in the Hymenoptera. It is present in all genera of Mutillidae, except one, *Rhopalomutilla* André, a highly specialized mutillid genus of the Oriental region. The presence of an anal lobe in the hind wings of the male *Chyphotes* Blake, *Apterogyna* Latreille, and *Pseudophotopsis* André and the incomplete fusion of the thoracic segments of the female *Typhoctes* Ashmead, *Chyphotes* Blake, and *Apterogyna* Latreille have led some authors to exclude these four genera from the Mutillidae.[10] This does not seem justified to the present authors. The presence of a "felt" line in both sexes of all genera of Mutillidae, except one highly specialized genus, and its absence in all other Hymenoptera, except the above four genera,

8 Buzicky, A. W., Ent. Amer., xxi (n.s.), pp. 201-243 (1941).

9 Malloch, J. R., Proc. U. S. Natl. Mus., lxviii, Art. 23, p. 3 (1926).

10 Reid, J. A. Trans. R. Ent. Soc. London, xci, Pt. 8, p. 399 (1941).

indicates to us the family rank of this character. Buzicky[8] has recently grouped *Apterogyna* and *Chyphotes* as the subfamily Apterogyninae in the Mutillidae. We would tentatively place *Typhoctes* and *Pseudophotopsis* with the Mutillidae also, at least until it can be demonstrated that they do not belong there. Their affinities in that family are by no means clear, because each of them is known only from a single sex. If this interpretation is correct, *Typhoctes* is automatically excluded from consideration as the female sex of *Brachycistis*, a genus that obviously belongs with the Tiphiidae.

The possibility that *Glyptometopa* might be the female sex of *Brachycistis* was suggested over thirty years ago by Turner,[11] who wrote that the male "may possibly show some affinity to *Brachycistis*." Mr. Turner also writes in a recent letter to the senior author, "Some thirty years ago I suggested that *Glyptometopa* Ashmead might be the female of *Brachycistis*." Turner's suggestion fell on deaf ears because Fox[4] had already placed females in the genus *Brachycistis* and his assignment of females to that genus had been accepted by Bradley.[5] It was not until the junior author[3] removed these females to *Myrmosa (Myrmosula)* that our minds were really open to suggestion regarding the females of *Brachycistis*. Turner[11] stated: "I consider it very doubtful if it [*Glyptometopa*] really belongs to the Thynnidae, although the thorax is similarly divided." Turner's doubt, as thus expressed, could have been made a certainty by a rigid application of the family diagnostic characters given by him,[11] "scape hollowed at the apex and almost concealing the first segment of the flagellum [*i. e.*, the pedicel]; thorax divided into three parts, including the median segment, more or less contracted in the middle." The scape of *Glyptometopa* is not hollowed at the apex, and the pedicel is not concealed; the thorax is tripartite, but is not contracted at the middle, in fact is actually expanded so that it is wider than the prothorax. Turner's diagnosis of the family Thynnidae is so loosely drawn that only a worker experienced in the Thynnidae would exclude *Glyptometopa* with assurance. The junior author has examined females of twenty-six of the forty-four thynnid genera which have described females. All the female Thynnids thus examined have the mesopleuron separated from the mesonotum by a distinct suture. The clypeus is moderately well developed in all of them. Most of the species of *Glyptometopa* and allies have the mesopleuron rounded into the mesonotum without any indication of a suture between them, although the species of *Aglyptacros*, new genus, have a weak suture present. The clypeus in all the species known at present is greatly reduced, consisting of a very narrow, transverse sclerite. The present authors think that the following characters are sufficient definitely to exclude *Glyptometopa* from the Thynnidae. The scape not concealing the pedicel,[12] the mesothorax expanded and wider than the prothorax or the propodeum, the

11 Turner, R. E., Genera Insectorum, Family Thynnidae, fasc. 105, pp. 55-56 (1910).

12 It should be pointed out that the pedicel is more or less hidden within a recess at the apex of the scape in most genera of Myzininae, so the character is not one of prime importance.

absence of a strongly developed suture between the mesopleuron and mesonotum, and the reduced clypeus. It is likewise excluded from the Mutillidae by the absence of "felt" lines on the second abdominal tergum and by the less specialized form of the thorax (*i. e.*, segments of the thorax much more distinct and with less fusion between them). The contiguous coxae and the absence of a platelike expansion of the metasternum over the hind coxae eliminate it from consideration in the Scoliidae.

With the Thynnidae, Mutillidae, and Scoliidae eliminated, the only place for *Glyptometopa* in our existing classification is in the Tiphiidae. The following points of similarity between *Glyptometopa* and the females of the more generalized subfamilies Tiphiinae and Myzininae may be noted: The noticeably inflated mesopleuron; the apical circlet of spines of the middle and hind tarsal segments; the inflated middle and hind femora; the fossorial middle and hind tibiae; and the quadrate, porrect, flattened head with small eyes and well developed vertex. The head is very much like that of the more specialized members of the *Meria* section of the Myzininae. The senior author has compared the male and female of *Braunsomeria* with *Brachycistis* males and *Glyptometopa* females. The similarity in the relationship between the habitus of the males and females in each case is striking. The differences due to sex in *Braunsomeria* are approximately the same in kind and degree as the differences between *Brachycistis* and *Glyptometopa*. Reid[10] has expressed the opinion that the females of *Brachycistis*, if wingless, may be expected to display a condition of the thorax similar to that of *Braunsomeria* spp.

From the standpoint of speciation *Glyptometopa* seems much more likely to be the female of *Brachycistis* than is *Typhoctes*. *Brachycistis* includes approximately fifty described species at present. We have examined numerous specimens of *Typhoctes* from Kansas, Colorado, Texas, New Mexico, Utah, Arizona, and California, all of which appear to represent a single species. The seventeen specimens of *Glyptometopa* which we have seen involve fourteen species distributed among eight groups of generic rank.

The two characters possessed by both *Brachycistis* males and *Glyptometopa* females which suggest their association are the brownish-orange to castaneous, glabrous integument of the body and the similarity in form of the hind coxae of the *castanea* group of *Brachycistis* and the new genus *Aglyptacros*. It was the similarity in habitus that led the senior author to investigate the possibilities of associating the two. We have arrived at the final conclusion by the process of deduction, eliminating one possibility here, confirming another there. The circumstantial evidence that the two groups represent the opposite sexes of the same subfamily is convincing and it is to be hoped that the capture of a pair *in copula* will eventually confirm this.

We think it is not necessary at the present time to make *Glyptometopa* a synonym of *Brachycistis*. If our conviction is ultimately verified and a critical study of *Brachycistis* results in its division into several additional genera, it may turn out that the genotype of *Brachycistis* and that of *Glyptometopa* will not be congeneric. In that case both names might be valid. We are therefore

restricting our discussion herein to the female sex represented by *Glyptometopa* and related genera. The senior author will discuss the generic characters of the brachycistidine males in a later paper.

In spite of the many years during which thousands of *Brachycistis* males have been collected, nothing is known of their biology, except that they are nocturnal (a few are crepuscular) and are attracted to lights. The uncertainty regarding the females which should be associated with them (some workers have not accepted the published suggestions regarding the female sex of *Brachycistis* and have considered that sex as entirely unknown) has led to much speculation concerning the identity and habits of the females.

Our biological knowledge of *Glyptometopa* and related females is exceedingly l ted. One female before us was captured beneath a street lamp on a sidewalk in a sand dune district of San Francisco. A second female was taken running over the ground in the Arizona desert in the daytime. Two additional females were captured in a special light trap designed by Mr. Theo. Zschokke for the very purpose of catching wingless Hymenoptera. Several years ago when Mr. Zschokke was collecting at Palm Springs, California, he cut out the top of a gallon fruit tin and placed the tin in the ground with the top rim flush with or slightly below the surface. A light was suspended over the trap. His idea was that wingless Hymenoptera might be attracted to lights at night, and that by placing the light over a trap in the ground the females would fall in when they crawled beneath the light. Two specimens were caught in this way. There is some indication, therefore, that the females are normally nocturnal like the brachycistidine males, and this may explain their paucity in collections.

Family TIPHIIDAE

Subfamily BRACHYCISTIDINAE

Diagnostic Characters.—Females: Head subquadrate, depressed, the posterolateral angles rounded, its median length from distal margin of clypeus to occiput equal to three-fourths to two-thirds its greatest width; clypeus very short, transverse; antennal fossae adjacent to anterior margin of front, thus situated very close behind mandibles (when closed); antennae 12-segmented, segments flattened and moniliform, except distal two or three which are terete and longer than preceding segments; compound eye small, one-third to one-half length of head, adjacent to base of mandible, almost flat (only very slightly convex), distinctly faceted, obovate, and without pubescence; ocelli absent; vertex with a pair of subcircular, subtriangular, or linear impressions at middle near posterior margin (the vertexal impressions of this paper); hypostomal and occipital carinae distinct, simple, complete, and well separated, except rarely ventral half, or lateral sectors of ventral half of occipital carina obsolete; maxillary palpi 6-segmented, except in *Aglyptacros*, in which they are 5-segmented; labial palpi 4-segmented.

Thorax longer than broad, the prothorax, fused mesonotum and mesopleuron, and fused metathorax and propodeum separated by well developed sutures; pronotum broader than long, lateral margins of dorsal surface straight

viewed from above, posterior margin slightly arcuate; mesothorax conspicuously broader than prothorax, mesopleuron sharply and triangularly inflated viewed from above; propodeum viewed from above with anterior margin much narrower than mesothorax, and expanding gradually to postero-lateral angles of dorsal surface, posterior margin of latter one and one-half times as wide as anterior margin; declivous posterior surface of propodeum narrowing to abdominal attachment; anterior declivity of pronotum, lateral margins of pronotal disk, sharp ridge on mesopleuron, lateral margins of dorsal and posterior surfaces of propodeum, and lateral surfaces of propodeum above, all with long, erect setae; mesosternum with a pair of large lamelliform processes overlying bases of middle coxae; metasternum variously developed, but not covering the hind coxae.

Wingless.

Legs moderately long; middle and posterior legs with femora and tibiae expanded, tibiae outwardly with short, stout spines; anterior tarsal segments short and with a well developed pecten along posterior margin; posterior tarsal segments rather long and slender; tarsal segments of both middle and posterior legs with a distal circlet of spines; tarsal claws simple; calcaria 1-1-2; anterior and posterior coxae contiguous, middle coxae separated.

Abdomen slightly longer than head and thorax combined and broader than either; first abdominal segment broadly sessile with the second; first tergum with anterior declivous portion perpendicular to posterior dorsal portion, but not separated from it by a transverse ridge or carina; first to sixth terga and second to fifth sterna each with a bowed line of single punctures separating each tergum or sternum into a large anterior area and a much smaller, subtriangular, posterior area, the latter always impunctate; all punctures bearing long, suberect setae; pygidial area not delimited.

Males: Genus *Brachycistis* and allies.

KEY TO GENERA

Females only

1. Proepisterna transversely elevated near ventral margin, but elevation rounded, not forming a distinct, transverse, elevated carina 2
   Proepisterna ventrally with an elevated, sharp, transverse carina extending from lateral margin to or almost to midline 5
2. Ventral half of occipital carina entirely absent ..... *Stilbopogon*, new genus
   Ventral half, as well as dorsal half, of occipital carina present and distinct 3
3. Mandibles broadest subapically, with a small tooth within at widest point, and setose beneath adjacent to tooth ..... *Glyptometopa* Ashmead
   Mandibles broadest at the base, gradually narrowed towards tip 4
4. Distance between hypostomal carina and occipital carina equal to approximately one-third length of proboscidal fossa; proepisterna punctate and only very faintly shagreened; ventral carina of mandible distinct but not high and prominent ..... *Glyptacros*, new genus
   Distance between hypostomal carina and occipital carina equal to approximately two-thirds length of proboscidal fossa; proepisterna very strongly shagreened and sparsely, transversely rugose; ventral carina of mandible lamelliform, high and prominent ..... *Xeroglypta*, new genus

5. Postero-lateral areas of vertex with a curved, densely setose sulcus...*Aulacros*, new genus
Postero-lateral areas of vertex without a curved, setose sulcus, but with a curved row of contiguous or separated punctures 6

6. Mandibles broadest subapically; first abdominal segment not at all petiolate; vertexal impressions present and distinct 7
Mandibles broadest very near base at a strong tooth, then gradually narrowed towards tip; first abdominal segment with a short, distinct petiole; vertexal impressions absent .....*Asligmometopa*, new genus

7. Posterior coxae not carinate on inner margin; proepisternal carina becoming obsolete towards midline; ventral half of occipital carina evenly arcuate throughout; maxillary palpi 6-segmented .....*Eurycros*, new genus
Posterior coxae with a strong, sharp carina on inner margin; proepisternal carina complete and prominent to midline; ventral half of occipital carina not evenly arcuate, rectangulate laterally, and forming a transverse, straight line on ventral aspect of head; maxillary palpi 5-segmented .....*Aglyptacros*, new genus

Genus GLYPTOMETOPA Ashmead

Glyptometopa Ashmead, Psyche, viii, p. 251 (1898).—Ashmead, Journ. N. Y. Ent. Soc., vii., p. 51 (1899).—Ashmead, Canad. Ent., xxxv, p. 156 (1903).—Turner, Genera Insectorum, Fam. Thynnidae, fasc. 105, p. 55 (1910).

Genotype.—*Glyptometopa americana* Ashmead. (Monobasic.)

It has not been possible to determine with any certainty with which group of brachycistidine males the female *americana* and its related species should be associated. Inasmuch as only *Brachycistis* antedates *Glyptometopa*, while *Brachycistina* Malloch and *Brachycistellus* Baker are of later dates, it may not be necessary to synonymize *Glyptometopa*.

Generic characters.—Female: Mandibles broadest subapically, with a small tooth within at its widest point, the tooth more or less concealed above and beneath by two or three scutate bristles; maxillary palpi 6-segmented; occipital carina complete and distinct on ventral half; distance between hypostomal carina and occipital carina equal to approximately half length of proboscidal fossa; vertexal impressions present and distinct; postero-lateral angles of vertex with a curved, setose sulcus.

Proepisternum somewhat transversely elevated near ventral margin, but elevation rounded, not at all carinate; metasternum compressed, elevated portion forming a Y-shaped carina.

Posterior coxae without a carina on inner margin; calcaria acute at tip.

First abdominal segment not petiolate.

Male.—Unknown.

KEY TO THE SPECIES

1. Mandibles with outer carina present, pseudotridentate; pronotum with a median, longitudinal, impressed line 2
Mandibles with outer carina absent, pseudoquadridentate; pronotum without a median, longitudinal, impressed line .....*convergens*, new species

2. Vertexal impressions short, their length approximately equal to transverse diameter of an antennal fossa, subparallel, only slightly diverging posteriorly; dorsum of propodeum with only a few (5) punctures on disk.....*americana* Ashmead

Vertexal impressions longer, one and one-fifth times transverse diameter of an antennal fossa, distinctly curved and strongly diverging posteriorly; dorsum of propodeum with more numerous punctures (about 15) on disk....*francisca*, new species

GLYPTOMETOPA AMERICANA Ashmead

Glyptometopa americana Ashmead, Psyche, viii, p. 251 (1898).—Turner, Genera Insectorum, Fam. Thynnidae, fasc. 105, p. 55 (1910).

Glyptometopa americana Ashmead, Canad. Ent., xxxv, p. 156 (1903).

Type:—Female, Alameda County, Calif., September (A. Koebele) [United States National Museum, Type No. 5052].

Female.—Length 4.0 mm. Brownish orange (the thorax darker, apparently because of mounting), with tip of mandibles castaneous.

Head glabrous; mandibles widest subapically, obtusely angulate on inner margin at widest point, a blunt tooth midway between inner obtuse angle and acute tip, thus pseudotridentate; mandibles setose beneath adjacent to inner obtuse angle, the latter not concealed from above and beneath by spatulate hairs present in other species (spatulate hairs obviously rubbed off in type); inner margin of mandible between obtuse tooth and base very weakly microserrulate; outer carina of mandible present on distal third, terminating at base of distal tooth; ventral mandibular carina present on distal third, not conspicuously elevated; scape somewhat compressed, narrowed ventral aspect densely setose, dorsal aspect with a dense tuft of setae distally; pedicel and first four flagellar segments with a cluster of several setae medially (flagellum beyond first segment missing, but presumably as described); front with small, subcontiguous, setose punctures between antennal fossae and inner margin of compound eye; inner margin of eye with a row of setose punctures; remainder of front and vertex with a very few, scattered punctures; curved, punctate, setose sulcus at postero-lateral angles of vertex extending anteriorly to a point opposite posterior margin of eye; vertexal impressions distinct, straight, subparallel, only slightly diverging posteriorly, their length approximately equal to transverse diameter of an antennal fossa, their anterior ends separated by a distance equal to twice their length; head between curved, punctate sulcus and occipital carina with a few, separated, small punctures; ventral aspect of head with a few scattered punctures.

Thorax glabrous, dorsum minutely and very delicately shagreened; pronotal disk with a median, longitudinal, impressed line and a few (four or five), scattered punctures, lateral margins with subcontiguous punctures; anterior declivous face of pronotum with more numerous punctures; lateral faces of pronotum with a very few (two or three), scattered punctures and ventral angle with a few, weak, oblique carinulae; mesonotum mostly impunctate, with a row of widely separated punctures (four to six) at anterior margin, similar submarginal punctures on lateral thirds of posterior margin, and subcontiguous punctures at lateral margins adjacent to declivous mesopleuron; dorsum of propodeum with five punctures on disk, three on one side of median line, two on the other, lateral margins with numerous subcontiguous punctures, and

posterior margin with ten to fifteen distinct, separated punctures; sides of propodeum with a few (three to six), scattered punctures, except that the dorsal margin is similar to the lateral margin of the dorsum of the propodeum.

Longer calcarium of hind tibiae distinctly curved.

Abdomen glabrous, minutely and delicately shagreened; declivous anterior face of first tergum minutely punctate, dorsal face with a few, larger, scattered punctures; succeeding terga with scattered punctures, those of the second more numerous than those of the third to fifth; first sternum with minute punctures at lateral margins; succeeding sterna with scattered, larger punctures, those of the second more numerous than those of the third to fifth; distal margin of pygidial tergum subtruncate.

Male.—Unknown.

Remarks.—Redescribed from the type specimen.

Glyptometopa francisca, new species
(Pl. 1, Figs. 1 and 2; Pl. 3, Fig. 14)

Holotype.—Female, San Francisco, Calif., August 13, 1941 (B. B. Prendergast) under lamp on street in sand dune district [California Academy of Sciences].

Female.—Length 5.0 mm. Brownish orange, with tip of mandible castaneous. Setae yellowish.

Head glabrous; mandible widest subapically, obtusely angulate on inner margin at widest point, a blunt tooth midway between inner obtuse angle and acute tip, thus pseudotridentate; mandible setose beneath adjacent to inner obtuse angle; a sinuate carina beginning proximad of the latter and extending along inner margin nearly to base; outer carina of mandible present on distal third, terminating at base of distal tooth; ventral mandibular carina present on distal third; scape somewhat compressed, narrowed ventral aspect densely setose, dorsal aspect with a dense tuft of setae distally; pedicel and first four flagellar segments with a cluster of several setae medially; front with small, dense, setose punctures between antennal fossae and inner margin of compound eye; inner margin of eye with a row of setose punctures; remainder of front and vertex with a few, scattered punctures; curved, punctate, setose sulcus at postero-lateral angles of vertex extending anteriorly to a point opposite posterior margin of eye; vertexal impressions distinct, densely punctate and setose, slightly curved and diverging posteriorly; distance between anterior ends of vertexal impressions equal to their length; head between curved, punctate sulcus and occipital carina with a median, elongate area of close punctures; ventral aspect of head with a few, scattered punctures.

Thorax glabrous; pronotal disk with a median, longitudinal, impressed line and scattered punctures (ten to twelve), lateral margins with contiguous punctures; anterior declivous face of pronotum with punctures more numerous and distinct; lateral faces of pronotum with a few (six to eight) scattered punctures, dorsal margin with contiguous punctures and ventral angle with a

few, weak, oblique carinulae; mesonotum mostly impunctate, with a row of widely separated punctures at anterior margin, similar submarginal punctures on lateral thirds of posterior margin, and dense punctures at lateral margins adjacent to declivous mesopleuron; dorsum of propodeum with about fifteen distinct punctures and lateral margins with dense punctures; sides of propodeum with scattered punctures, except that the dorsal margin has dense punctures.

Longer calcarium of hind tibiae distinctly curved.

Abdomen glabrous, minutely and delicately shagreened in part; declivous, anterior face of first tergum minutely punctate, dorsal face with larger scattered punctures, except that the lateral margins have close punctures; succeeding terga with scattered punctures, those of the second more numerous than those of the third to fifth; first sternum with close, minute punctures anteriorly and scattered ones elsewhere; succeeding sterna with scattered, larger punctures, those of the second more numerous than those of the third to fifth; distal margin of pygidial tergum subtruncate.

Male.—Unknown.

Remarks.—We are doubtful that this should be recognized as a species distinct from *americana* Ashmead, but it differs from Ashmead's type in having the vertexal impressions longer, curved, and strongly diverging posteriorly, in the more numerous punctures of the pronotum and dorsum of the propodeum (disks), and in having the ventral mandibular carina higher and more conspicuous. We believe that it is more practical to recognize it for the present with a name than to identify it with *americana*. The collection of numerous additional specimens in the San Francisco Bay area would probably facilitate a decision as to the specific validity of this San Francisco specimen.

Glyptometopa convergens, new species

(Pl. 3, Fig. 13)

Holotype.—Female, Santa Monica, Calif., June 6, 1901 (C. E. Hutchinson) [United States National Museum, Type No. 56211].

Female.—Length 6.0 mm. Brownish orange with apex of mandible castaneous. Setae yellowish.

Head glabrous; mandible widest subapically, with a short, blunt, distinct inner tooth at widest point, and a thin lamella, slightly emarginate medially, extending from inner tooth to acute apex, thus pseudoquadridentate; mandible setose beneath adjacent to inner tooth; inner margin of mandible straight between inner tooth and base, neither carinate nor dentate; outer mandibular carina entirely absent; ventral mandibular carina present on distal third; scape somewhat compressed, the narrowed, ventral aspect densely setose, the dorsal aspect with a dense tuft of setae distally; pedicel and first four flagellar segments with a cluster of several setae medially; front with dense, minute, setose punctures between antennal fossa and eye margin; inner margin of eye with a row of contiguous, setose punctures extending slightly posterior to posterior margin of eye; curved, punctate sulcus of postero-lateral angles of vertex extending anteriorly to a point opposite posterior margin of eye; vertexal

impressions short, elongate, oblique, diverging posteriorly, distance between their anterior end one and one-half times their length; area between curved sulcus of postero-lateral angles and occipital carina with weak, scattered punctures.

Thorax glabrous; pronotal disk without a median, longitudinal, impressed line and with only a few, scattered punctures posteriorly, except that the lateral margins have dense, setose punctures; anterior, declivous face of pronotum with numerous distinct punctures; dorsal margin of lateral face of pronotum with dense, setose punctures, otherwise with a few, scattered punctures; mesonotum with a very few, scattered punctures, mostly at anterior and posterior margins; dorsal surface of propodeum with scattered punctures, most of them toward middle, lateral and posterior margins closely, setosely punctured, setae thick and conspicuous; posterior face of propodeum with numerous, minute punctures caudad of an anterior impunctate strip; sides of propodeum with close, setose punctures at dorsal margin, elsewhere with small, scattered punctures.

Longer calcarium of hind tibiae distinctly curved.

Abdomen glabrous, minutely and delicately shagreened in part; anterior declivous face of first tergum minutely punctured, dorsal face with scattered punctures, except that the punctures are close at the lateral margins; succeeding terga with scattered punctures, those of the second more numerous than those of the third to fifth; first sternum glabrous, with scattered, minute punctures; succeeding sterna with scattered punctures; distal margin of pygidial tergum subtruncate.

Male.—Unknown.

Remarks.—Differs from *americana* and *francisca* in the pseudoquadridentate mandibles with the outer carina absent, in the shape and extent of the vertexal impressions, and in the absence of the median, impressed line on the pronotum.

Stilbopogon, new genus

Genotype.—*Stilbopogon alutacea,* new species.

It has not been possible to associate this genus with any definite group of male Brachycistidinae.

Generic characters.—Female: Mandibles broadest subapically, inner margin obtusely angulate at broadest point and with two or three short, stiff bristles at angle; the same margin distinctly, narrowly emarginate at base of the long, slender, apical tooth, thus pseudotridentate (*i. e.*, the long apical tooth, an obtuse angle at emargination, and an obtuse angle at broadest point); outer mandibular carina high and thin, extending from base of the slender, apical tooth proximad about one-third length of mandible, its margin weakly, finely crenulate; ventral mandibular carina high and prominent on distal half of mandible; maxillary palpi presumably 6-segmented (not visible in specimens at hand); occipital carina obsolete and entirely absent on ventral half; distance between hypostomal carina and concave area surrounding foramen equal to

about one and one-third times length of proboscidal fossa; vertexal impressions punctiform, small; postero-lateral angles of vertex with a curved, setose sulcus.

Ventral margin of proepisternum elevated, rounded, not at all carinate; metasternum compressed, Y-shaped, extending beneath mesosternal plates but not between them.

Posterior coxae without a carina on inner margin; calcaria acute at tip.

First abdominal segment not petiolate.

Male.—Unknown.

Remarks.—Differs from *Glyptometopa* and all other genera in having the ventral half of the occipital carina entirely absent, the hypostoma thus much longer than in the other genera.

Stilbopogon alutacea, new species

(Pl. 2, Fig. 9; Pl. 3, Fig. 15)

Holotype.—Female, Deming, N. Mex., September 30, 1899 (J. L. Zabriskie from H. F. Wickham) [American Museum of Natural History].

Paratype.—Female, Presidio, Tex., July 30, 1930 (E. R. Tinkham) [University of Minnesota].

Female.—Length 4.0 mm. Brownish orange, except tip of mandible, which is castaneous. Setae yellowish.

Head glabrous, shining, both above and beneath; mandible widest subapically (see generic description); front and vertex almost impunctate, inner and upper margins of eyes without a row of punctures; curved, punctate, setose sulcus at postero-lateral angles of vertex short, extending only half distance to posterior margin of eye; vertexal impressions small, punctiform, very close together, each impression with one or two setae; genae with a few, scattered punctures; hypostoma almost impunctate, much longer than proboscidal fossa (see generic description); scape compressed, narrowed ventral aspect densely setose, dorsal aspect with a dense tuft of setae distally; pedicel and first three flagellar segments with several setae medially on outer aspect.

Thorax glabrous, shining, dorsum minutely and delicately shagreened, its length from neck to abdominal attachment one and two-thirds times its width at and including mesopleural ridges; disk of pronotum with its median length about half its greatest width, impunctate; lateral face of pronotum with a few, subcontiguous punctures above; mesonotum with a few, subcontiguous punctures laterally forming a row, and with only one or two punctures along anterior and posterior margins which do not form rows, the disk impunctate; dorsal surface of propodeum with several, scattered punctures on disk and some contiguous ones laterally; posterior surface of propodeum with minute, distinct punctures; sides of propodeum impunctate.

Longer calcarium of hind tibiae narrow, about three-fifths length of metatarsus, acute at tip.

Abdomen glabrous, shining, minutely and delicately shagreened in part;

anterior declivous face of first tergum minutely punctured, dorsal face with larger, scattered punctures; succeeding terga with sparse, scattered punctures; first sternum coarsely shagreened; succeeding sterna with a few, small, scattered punctures; distal margin of pygidial tergum rounded.

Male.—Unknown.

Glyptacros, new genus

Genotype.—*Glyptacros angustior*, new species.

It has not been possible to associate this genus with any definite group of male Brachycistidinae.

Generic characters.—Female: Mandibles broadest at base, gradually narrowed towards tip, inner margin interrupted at about three-fifths distance from base by a projecting carina forming two small teeth, thus edentate at tip and with two small teeth within; outer mandibular carina represented by a convex ridge beginning slightly before middle and extending towards tip; ventral mandibular carina distinct, but only moderately high, beginning slightly before middle and extending toward tip; maxillary palpi 6-segmented; occipital carina complete, present and distinct; distance between hypostomal carina and occipital carina equal to approximately one-third length of proboscidal fossa; postero-lateral angles of vertex with a curved, setose sulcus.

Ventral margins of proepisterna elevated, rounded, not at all carinate; metasternum compressed, Y-shaped, extending beneath mesosternal plates, but not between them.

Posterior coxae without a carina on inner margin; posterior calcaria spatulate at tip.

First abdominal segment not petiolate.

Male.—Unknown.

Remarks.—Differs from *Glyptometopa* and *Stilbopogon* in having the mandibles broadest at the base and gradually narrowed towards the tip; it differs further from *Stilbopogon* by the presence of a complete occipital carina.

KEY TO THE SPECIES

1. Anterior margin of clypeus very shallowly, broadly concave, not at all dentate; vertexal impressions short, elliptical, slightly but distinctly converging anteriorly; proepisterna with moderate, distinct punctures, the ventral, elevated margins glabrous, impunctate ..... *angustior*, new species

Anterior margin of clypeus distinctly arcuate, and with lateral angles in front of midline of antennal fossa strongly, bluntly dentate; vertexal impressions long, linear, subparallel; proepisterna with small, close punctures throughout, including the ventral, elevated margins ..... *ashmeadi*, new species

Glyptacros angustior, new species

(Pl. 2, Fig. 10; Pl. 3, Fig. 16)

Holotype.—Female, Arizona [Academy of Natural Sciences of Philadelphia].

Female.—Length 6.5mm. Brownish orange, except distal third of mandible, which is castaneous. Setae very pale yellowish.

Head glabrous, shining, both above and beneath; mandible widest basally, with a distinct, blunt, rounded tooth directed forward and separated from body of mandible by a notch about three-fifths distance from base to tip, and a small, inconspicuous denticle on inner margin somewhat proximad of the blunt tooth; proximal half of mandible beneath setose; anterior margin of clypeus very shallowly, broadly concave, not at all dentate laterally; interantennal space densely setose at anterior margin adjacent to clypeus; scape somewhat compressed, narrowed ventral aspect densely setose, dorsal aspect with a dense tuft of setae distally; pedicel and proximal flagellar segments with several setae medially on outer aspect (segments beyond third missing); vertexal impressions elliptical, distinctly converging anteriorly; genae with only a few, scattered punctures; hypostoma and postgenae with a few, distinct punctures adjacent to margin of proboscidal fossa.

Thorax glabrous, shining, its length from neck to abdominal attachment one and four-fifths times its width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, and with almost no punctures, except contiguous ones along lateral margins and separated ones at anterior margin adjacent to thoracic neck; lateral surface of pronotum with only a few punctures, and with oblique, obscure carinulae ventrally; mesonotum with two punctures each side of midline on anterior margin, a row of subcontiguous punctures at lateral margins and lateral thirds of posterior margin, otherwise impunctate; dorsal surface of propodeum with contiguous, small punctures along lateral margins, subcontiguous punctures along posterior margin, and lateral areas of disk with a few, large punctures on posterior two-thirds; posterior surface of propodeum with numerous, minute punctures below an impunctate strip; lateral surfaces of propodeum impunctate, except a row of contiguous punctures at dorsal margin; metasternum with arms of Y-shaped carina strongly diverging and arcuate.

Posterior calcaria not acute at tip, very slightly blunted and rounded.

Abdomen glabrous, shining, very faintly, minutely, and delicately shagreened; anterior declivous face of first tergum minutely punctured, dorsal face with larger, separated punctures; succeeding terga with sparse, scattered punctures; first sternum glabrous, shining, impunctate; anterior half of second sternum with sparse to subcontiguous, moderate punctures; succeeding sterna with a few, small, scattered punctures; distal margin of pygidial tergum rounded.

Male.—Unknown.

Glyptacros ashmeadi, new species

(Pl. 2, Fig. 8)

Holotype.—Female, without locality data [collection of C. T. Brues].

Female.—Length 7.0 mm. Brownish orange, except distal third of mandible, which is castaneous. Setae pale yellowish.

Head glabrous, shining, both above and beneath; mandible widest basally,

with a distinct, blunt, rounded tooth directed forward and separated from body of mandible by a small notch about two-thirds distance from base to tip, and with a small, inconspicuous denticle on inner margin and somewhat proximad of the blunt tooth; proximal half of mandible beneath setose; anterior margin of clypeus distinctly arcuate, lateral angles, in front of midline of antennal fossa, strongly, bluntly dentate; interantennal space with thick setae at anterior margin adjacent to clypeus; scape somewhat compressed, the narrowed, ventral aspect densely setose, dorsal aspect with a dense tuft of setae distally; pedicel setose, dorsal aspect with a dense tuft of setae distally; pedicel and four proximal flagellar segments with several setae medially on outer aspect; vertexal impressions long, linear, subparallel, a row of contiguous, setose punctures at bottom of impression; genae with only a few, scattered punctures; hypostoma and postgenae with a few, distinct punctures adjacent to margin of proboscoidal fossa.

Thorax glabrous, shining, its length from neck to abdominal attachment one and four-fifths times its width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, almost without punctures, except contiguous ones along lateral margins, separated ones at the anterior margin adjacent to the thoracic neck, and three or four punctures at the posterior margin on each side near postero-lateral angles; lateral surface of pronotum with a few, scattered punctures and with oblique, obscure carinulae ventrally; mesonotum with a row of widely separated punctures at anterior margin, contiguous punctures at lateral margin, and a curved row of close punctures beginning at middle of sides submarginally and extending to and along posterior margin toward median line; dorsal surface of propodeum with contiguous, small punctures along lateral margins, subcontiguous punctures along posterior margin, and with moderately large, scattered punctures on disk; posterior surface of propodeum with numerous, minute punctures below an impunctate strip; dorsal half of lateral surfaces of propodeum punctate, ventral half impunctate, punctures of dorsal half moderate, sparse ventrally, becoming close and contiguous towards dorsal margin; proepisterna with small, close punctures throughout, including ventral, elevated margins; metasternum less compressed than in *angustior*, Y-shaped, arms of the Y very broad, not carinate, the broad surface densely, finely punctate.

Posterior calcaria distinctly spatulate at tip.

Abdomen glabrous, shining, very faintly, minutely, and delicately shagreened; anterior, declivous face of first tergum minutely punctured, dorsal face with sparse, larger punctures; succeeding terga with sparse, scattered punctures; first sternum faintly rugoso-punctate; anterior half of second sternum with sparse to subcontiguous, moderate punctures; succeeding sterna with a few, small, scattered punctures; distal margin of pygidial tergum rounded.

Male.—Unknown.

Remarks.—Differs from *angustior* by the arcuate and dentate, anterior margin of the clypeus, the subparallel, linear vertexal impressions, the more closely and extensively punctate proepisterna, the more extensively punctate lateral surfaces of the propodeum ,and the broad, densely punctate arms of the Y-shaped metasternum.

Xeroglypta, new genus

Genotype.—*Xeroglypta egregia,* new species.

It has not been possible to associate this genus with any definite group of male Brachycistidinae.

Generic characters.—Female: Mandibles broadest at base, gradually narrowed towards tip, inner margin interrupted about three-fifths distance from base to tip by a short, projecting carina forming two obscure teeth; outer carina of mandible distinct, but blunt, extending about two-fifths distance from middle to tip; ventral carina lamelliform, high and sharp, present on distal three-fifths of mandible; occipital carina complete, present and distinct; maxillary palpi 6-segmented; distance between hypostomal carina and occipital carina equal to approximately two-thirds length of proboscidal fossa; postero-lateral angles of vertex with a curved, setose sulcus.

Ventral margins of proepisterna elevated and angulate, but not carinate; proepisterna very strongly shagreened, sparsely transversely rugose; metasternum compressed, Y-shaped, stem of Y largely concealed by mesosternal plates, arms of Y straight and only moderately diverging.

Posterior coxae without a carina on inner margin; posterior calcaria spatulate at tip.

Male.—Unknown.

Remarks.—The form of the mandibles recalls *Glyptacros* at once, but the ventral carina is thinner, much higher, and sharper; the distance between the hypostomal and occipital carinae is approximately twice as great as in *Glyptacros* in terms of the length of the proboscidal fossa; and the entire body is more strongly shagreened than in *Glyptacros,* the proepisterna being conspicuously so and sparsely rugose as well.

Xeroglypta egregia, new species

(Pl. 3, Fig. 18)

Holotype.—Female, Palm Springs, Calif., May 2-7, 1933 (Theo. Zschokke) [University of Minnesota].

Paratype.—Female, same data as type [United States National Museum].

Female.—Length 5.0 mm. Brownish orange, except tip of mandibles, which is castaneous, and flagellum, which is pale yellow. Setae yellowish golden.

Head delicately but distinctly shagreened; mandible widest at base (see generic description); anterior margin of clypeus straight, not at all dentate; interantennal space setose at anterior margin; scape somewhat compressed, narrowed, ventral aspect thickly setose, dorsal aspect with a dense tuft of long setae distally; pedicel and first four flagellar segments with several setae medially on outer aspect; inner eye margins with a row of subcontiguous punctures extending slightly posterior to upper margin of eye; space between eye and curved, setose sulcus with scattered, distinct punctures; vertexal impressions arcuate, converging anteriorly and curving outwards posteriorly; genae and

ventral surface of head with scattered, small, indistinct punctures, margins of proboscidal fossa almost impunctate.

Thorax distinctly shagreened, its length from neck to abdominal attachment one and one-half times its width at and including mesopleural ridges, pronotal disk with its median length slightly more than one-third its greatest width, with a few, scattered, indistinct punctures, except contiguous punctures at lateral margins and sparse, indistinct punctures adjacent to thoracic neck; lateral surfaces of pronotum with scattered, small punctures and with oblique, obscure carinulae ventrally; mesonotum without punctures at anterior margin, with scattered punctures on lateral areas, and contiguous punctures at extreme lateral margins; anterior fourth of dorsum of propodeum impunctate, remainder of disk with sparse, distinct punctures, lateral margins with contiguous punctures; posterior face of propodeum with a row of contiguous punctures at dorsal margin, dorsal fourth otherwise impunctate, remainder with numerous, minute punctures; lateral surfaces of propodeum with small, subcontiguous punctures at dorsal margin, anterior and dorsal areas with scattered, small punctures, otherwise impunctate; proepisterna (see generic description); metasternum (see generic description).

Abdomen distinctly shagreened; anterior declivous face of first tergum minutely punctured, dorsal face with distinct, larger punctures; succeeding terga decreasingly, sparsely punctate; first sternum practically impunctate, succeeding sterna decreasingly sparsely punctate; distal margin of pygidial tergum rounded.

Male.—Unknown.

Remarks.—Both specimens collected in a light trap, the trap placed in the ground as described in the introductory paragraphs.

Aulacros, new genus

Genotype.—*Aulacros latior,* new species.

It has not been possible to associate this genus with any definite group of male Brachycistidinae.

Generic characters.—Female: Mandibles broadest subapically at approximately two-thirds distance from base to tip, inner margin with a large obtuse tooth at broadest point and a blunt, rounded tooth slightly distad of latter; tip of large, obtuse, mandibular tooth largely concealed by two or three, ventral, scutate bristles and one very large, dorsal, scutate bristle; inner margin of mandible between large tooth and base irregularly serrate; outer and ventral carinae of mandible distinct, beginning a very short distance before middle and extending toward tip; maxillary palpi 6-segmented; occipital carina present and distinct both dorsally and ventrally; distance between hypostomal carina and occipital carina equal to approximately one-third length of proboscidal fossa; postero-lateral areas of vertex with a strong, densely setose, curved sulcus.

Ventral margin of proepisterna elevated, strongly and sharply carinate, except that the carina becomes weak towards the midline; metasternum large,

not compressed although more or less Y-shaped, the stem of the Y with three, very close, parallel carinae, the arms of the Y forming broad, slightly elevated processes.

Posterior coxae not carinate on inner margin; posterior calcaria spatulate at tip.

Male.—Unknown.

Remarks.—Similar to the preceding genera in the presence of the curved, setose sulci on the vertex. Differs from these genera in having the proepisterna strongly carinate ventrally and in the much more strongly developed metasternum. The mandibles are of the same general type as in *Glyptometopa*, but the inner margin is serrate.

Aulacros latior, new species

(Pl. 2, Fig. 11; Pl. 3, Fig. 20)

Holotype.—Female, Palm Springs, Calif., May 7, 1927 (A. C. Davis) [California Academy of Sciences].

Female.—Length 8.0 mm. (the actual length may be somewhat longer, as the terminal abdominal segments are telescoped slightly more than usual). Brownish orange, tips of mandibles castaneous. Setae yellowish golden.

Head glabrous, shining; mandibles (see generic description) setose beneath, with a row of setae on outer surface adjacent to and above ventral carina, and a tuft of setae at base on outer surface; clypeus and interantennal space more or less shagreened; anterior margin of clypeus straight, except that it is slightly angulate or subdentate at the lateral angles anterior to the midline of the antennal fossae; anterior margin of interantennal space setose; scape somewhat compressed, the narrowed ventral aspect thickly setose, dorsal aspect with a dense tuft of long setae distally; pedicel and first four flagellar segments with several setae medially on outer aspect; frontal area immediately posterior to antennal fossae, and especially between latter and eye margins, thickly setose; inner eye margins with a row of punctures extending above posterior margin of eye; front and vertex elsewhere with very few, scattered punctures; vertexal impressions linear, subparallel, with thick, very long setae; postgenae and hypostomal area with sparse, distinct punctures, the latter becoming contiguous in area between the hypostomal and occipital carinae.

Thorax glabrous, very weakly and delicately shagreened, its length from neck to abdominal attachment one and one-third times its width at and including mesopleural ridges; neck strongly shagreened and thickly setose; pronotal disk with its median length approximately one-third its greatest width, and with scattered, setose punctures, lateral margins with several rows of contiguous, smaller punctures, and posterior margin with a single row of punctures separated by about their own width, more or less obsolete medially; upper half of lateral surface of pronotum glabrous, impunctate, lower half sparsely punctate and ventral margins closely punctate; mesonotum impunctate, except a row of separated punctures at anterior margin, a row at posterior margin, and a longitudinal, slightly curved row extending from anterior to posterior margins at probable site of mesonotal-mesopleural suture; dorsal surface of

mesopleura impunctate, except contiguous, setose punctures at lateral and posterior margins; dorsal surface of propodeum with anterior fourth and a median area the length of the surface impunctate, lateral areas thus set off with distinct, separated punctures; lateral and posterior margins of dorsal surface with contiguous and subcontiguous, setose punctures, thus lateral and posterior margins with a thick fringe of long setae; posterior face of propodeum minutely, closely punctate, except a narrow, transverse, dorsal band, which is glabrous, impunctate; lateral surfaces of propodeum with very sparse, small punctures, irregularly distributed throughout.

Abdomen shining, delicately shagreened throughout; declivous anterior face of first tergum closely, minutely punctate; dorsal surface of same tergum with contiguous punctures laterally and scattered, larger punctures medially; succeeding terga with smaller and fewer punctures successively; first sternum closely, shallowly punctate and longitudinally carinulate medially; second sternum with small, separated punctures, closer anteriorly and posteriorly; succeeding sterna with few punctures; pygidial tergum rounded at distal margin.

Male.—Unknown.

Eurycros, new genus

Genotype.—*Eurycros furtivus*, new species.

It has not been possible to associate this genus with any definite group of male Brachycistidinae.

Generic characters.—Female: Mandibles broadest subapically at approximately two-thirds distance from base to tip, inner margin with a large, obtuse tooth at broadest point and a blunt, rounded tooth slightly distad of latter; tip of obtuse tooth concealed by scutate bristles above and beneath, with at least two beneath and one above; inner margin of mandible serrate between obtuse tooth and base; outer carina of mandible sharp and distinct; ventral carina of mandible sharp and distinct, outer carina beginning at middle of mandible and extending towards tip, ventral carina beginning slightly distad of outer one; mandibles setose beneath; maxillary palpi 6-segmented; occipital carina present and distinct both dorsally and ventrally; distance between hypostomal and occipital carinae approximately equal to four-fifths length of proboscidal fossa; postero-lateral areas of vertex with a curved row of subcontiguous punctures, not sulcate.

Ventral margin of proepisterna elevated, strongly and sharply carinate, except that the carina becomes obsolete towards the midline; metasternum compressed anteriorly, but triangular posteriorly, triangular area densely, minutely punctate and its posterior angles elevated into dentate processes.

Posterior coxae not carinate on inner margin; posterior calcaria slightly curved and weakly spatulate at tip.

Male.—Unknown.

Remarks.—Differs from *Aulacros* in the absence of the setose sulcus at the postero-lateral angles of the vertex, the sulcus being replaced by a curved row of

punctures; by the greater distance between the hypostomal and occipital carinae; by the triangular, punctate, and dentate posterior area of the metasternum; and by the much less setose body.

Eurycros furtivus, new species
(Pl. 3, Fig. 21)

Holotype.—Female, Tucson, Ariz., July 5, 1932 (R. A. Flock) [University of Minnesota].

Paratype.—Female, Avondale Ranch, Agua Fria River, Ariz., August 8, 1917 (Wheeler) [collection of C. T. Brues].

Female.—Length 6.5 mm. Brownish orange, tips of mandibles castaneous, legs yellowish brown, and flagellum yellowish. Setae dark yellowish golden.

Head glabrous, shining, very faintly and delicately shagreened; mandibles (see generic description); anterior margin of clypeus almost straight, very slightly concave, slightly angulate laterally anterior to midline of antennal fossae; interantennal space bare, except a row of sparse setae at its anterior margin adjacent to clypeus; scape somewhat compressed, narrowed ventral aspect thickly setose, dorsal aspect with a dense tuft of setae distally; pedicel and first three flagellar segments with one or two setae medially on outer aspect; front and vertex almost impunctate, except an irregular row of subcontiguous punctures at anterior margin just posterior to antennal fossae, a few separated punctures adjacent to inner and posterior margins of eyes, and two or three punctures medially considerably anterior to vertexal impressions, the latter short, elliptical and oblique, almost punctiform, strongly converging anteriorly; genae with very sparse, distinct punctures; ventral surface of head with a few, scattered punctures.

Thorax glabrous, distinctly and delicately shagreened, its length from neck to abdominal attachment one and one-half times its width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, almost impunctate, with one or two punctures on each side of longitudinal midline and slightly posterior to transverse midline, and a row of subcontiguous punctures at lateral margins; lateral surface of pronotum with scattered, obscure punctures; mesonotum almost impunctate, with two punctures at anterior margin each side of midline, a third puncture posterior to anterior pair, and a row of widely separated punctures at posterior margin becoming contiguous at lateral margins; dorsum of propodeum almost impunctate, with four or five punctures each side posterior to transverse midline, a transverse row of deeper, coarser, subcontiguous punctures at junction of dorsum and posterior face, and a row of subcontiguous punctures at lateral margins; posterior face of propodeum with upper third to half impunctate, remainder minutely punctured; sides of propodeum impunctate, except that dorsally and posteriorly it has obscure, subcontiguous punctures; proepisterna strongly shagreened and with distinct, close punctures towards ventral margin.

Abdomen shining, distinctly and delicately shagreened throughout; decli-

vous, anterior surface of first tergum minutely punctate throughout, dorsal surface with sparse punctures; succeeding terga with only a few, scattered punctures; first sternum impunctate, except anterior third, which has close, confluent punctures, and posterior margin, which has minute, close punctures; second sternum with sparse, scattered punctures, becoming closer towards anterior margin; remaining sterna with only a few, scattered punctures; pygidial tergum rounded at posterior margin.

Male.—Unknown.

Astigmometopa, new genus

Genotype.—*Astigmometopa emarginata,* new species.

This monotypic genus cannot be associated positively with any group of male Brachycistidinae, but speculation would suggest Malloch's[9] *nitida* group and the species *cremastogaster* Melander, which has been taken at the same time and place as *emarginata* by Dr. P. A. Readio.

Generic characters.—Female: Mandibles broadest subbasally at an obtuse tooth formed by a deep, rounded emargination between it and base of mandible, then gradually narrowed towards tip; outer carina of mandible entirely absent; carina moderate and extending proximally almost to the base of the mandible; ventral, mandibular carina separated from dorsal body of mandible by a setose sulcus extending proximad two-thirds length of mandible; inner ventral surface of mandible setose; maxillary palpi 6-segmented; occipital carina present and distinct both dorsally and ventrally; distance between hypostomal carina and occipital carina equal to four-fifths the length of the proboscidal fossa; vertexal impressions absent; postero-lateral angles of vertex without a thickly setose sulcus, but with a row of subcontiguous, setose punctures.

Ventral margin of proepisterna sharply carinate, the carina becoming weaker towards midline; metasternum compressed anteriorly between middle coxae, but expanded posterior to latter and subtriangular, posterior angles of triangular area elevated and rounded.

Posterior coxae not carinate on inner margin; posterior calcaria curved and acute at tip.

First abdominal segment with a short but distinct petiole.

Male.—Unknown.

Remarks.—Differs from any other described genus of female Brachycistidinae in the form of the mandibles, the absence of the vertexal impressions, and the petiolate first abdominal segment. Similar to *Eurycros* in the form of the proepisterna and the curved row of setose punctures at the postero-lateral angles of the vertex.

Astigmometopa emarginata, new species

(Pl. 3, Fig. 17)

Holotype.—Female, Valentine, Tex., July 13, 1927 (P. A. Readio) [University of Kansas].

Female.—Length 9.5 mm. Brownish orange throughout, except the mandibles which are almost entirely castaneous. Setae pale yellow.

Head glabrous, shining, not shagreened; mandibles (see generic description); anterior margin of clypeus almost straight, very slightly concave, anterior margin of head laterad of clypeus broadly, roundly emarginate; interantennal area with a few setae anteriorly adjacent to posterior margin of clypeus; scape somewhat compressed, narrowed ventral aspect thickly setose, dorsal aspect with only a sparse tuft of setae distally; pedicel and first four flagellar segments with one to several setae on outer aspect; front with a narrow, transverse area of distinct, separated punctures just posterior to antennal fossae and extending from one eye margin to the other; front and vertex with very sparse, scattered punctures, irregularly arranged and more numerous towards postero-lateral angles; genae with only a few, scattered punctures; ventral surface of head with only a very few, scattered punctures.

Thorax glabrous, shining, very faintly and indistinctly shagreened, its length from neck to abdominal attachment almost but not quite twice its width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, with sparse, scattered punctures anteriorly and laterally, and with contiguous punctures at lateral margins; lateral surface of pronotum sparsely punctate on dorsal third, remainder longitudinally carinulate; mesonotum not visible medially, but with subcontiguous punctures laterally, and with contiguous punctures at lateral angles; dorsum of propodeum with sparse, scattered punctures throughout, a row of subcontiguous punctures at the junction of the dorsum and posterior face and with contiguous punctures at the lateral margins; posterior surface of propodeum minutely punctate; lateral surface of propodeum impunctate, except dorsal margin, which has contiguous punctures; proepisterna with subcontiguous to contiguous punctures on disk, the broad, ventral margin impunctate; postero-lateral angles of metasternum with deep, contiguous punctures.

Abdomen glabrous, shining, faintly shagreened; anterior, declivous surface of first tergum closely punctate, dorsal surface very sparsely punctate, except lateral margins of dorsal surface, which are contiguously punctate; succeeding terga with only a few, scattered punctures; first sternum longitudinally rugose throughout; succeeding sterna very sparsely punctate; pygidial tergum rounded at posterior margin.

Male.—Possibly *Brachycistis cremastogaster* Melander.

Aglyptacros, new genus

Clyptometopa Banks, Canad. Ent., xliv, p. 202 (1912).

Genotype.—*Glyptometopa eureka* Banks (=*Aglyptacros eureka* Banks).

This genus cannot be positively associated with any group of male Brachycistidinae, but if the carinate, posterior coxae can be used as a criterion, it may represent the opposite sex of Malloch's[9] *castanea* Group.

Generic characters.—Female: Mandibles broadest subapically at approximately two-thirds distance from base to tip, inner margin with a large, obtuse tooth at broadest point and slightly arcuately produced a short distance distad of obtuse tooth; inner margin proximad of obtuse tooth with three small teeth, the two distal ones distinct and conspicuous, the proximal one weak and indis-

tinct; tip of obtuse tooth concealed by scutate bristles above and beneath; outer carina of mandible weak and indistinct, almost obsolete; ventral carina of mandible distinct and sharp; mandibles setose beneath; maxillary palpi 5-segmented; occipital carina present and well developed ventrally, but not evenly arcuate throughout, distinctly rectangulate laterally and forming a transverse, straight line across posterior, ventral surface of head; distance between occipital and hypostomal carinae equal to approximately half length of proboscidal fossa; vertexal impressions present; postero-lateral angles of vertex without a densely setose sulcus, but with a row of curved punctures.

Ventral margin of proepisterna very strongly elevated and sharply carinate their entire width; metasternum triangular.

Posterior coxae strongly carinate on inner margin; posterior calcaria slightly curved and acute at tip.

Male.—Probably *castanea* group of Malloch.

Remarks.—Differs from all the preceding genera in the 5-segmented maxillary palpi, the angulate, occipital carina, and the carinate, posterior coxae.

KEY TO THE SPECIES

1. Ventral, transverse sector of occipital carina not crenulate, strongly elevated each side of midline; lateral sector of occipital carina present and complete, uniting ventrally with transverse sector; mesonotal-mesopleural suture more or less obsolete; median, longitudinal sulcus of first sternum reduced, present only on anterior third 2

   Ventral, transverse sector of occipital carina crenulate, interrupted medially, neither elevated nor angulate adjacent to interruption; lateral sector of occipital carina incomplete, not reaching lateral end of transverse sector; mesonotal-mesopleural suture present and distinct; median, longitudinal sulcus of first sternum extending posterior to transverse midline 3

2. Ventral, transverse sector of occipital carina distinctly interrupted at midline, strongly elevated and dentate each side adjacent to interruption; lateral sector of occipital carina uniting ventrally with transverse sector in a distinct angle; posterior to transverse sector of occipital carina a medially interrupted, transverse, angulate carina without curved prominences; mesonotal-mesopleural suture almost obsolete, only faintly visible in certain lights..... *segredentatus*, new species

   Ventral, transverse sector of occipital carina not interrupted, stongly elevated in a rounded lobe each side of midline; lateral sector of occipital carina uniting ventrally with transverse sector in an even curve; posterior to transverse sector of occipital carina a transverse, angulate carina with two low, rounded prominences directly behind lobes of occipital carina; mesonotal-mesopleural suture somewhat more distinct ..... *eureka* (Banks)

3. Ventral, transverse sector of occipital carina extending laterally considerably beyond point where lateral sector would join it if latter were present; vertexal impressions linear, consisting of a row of contiguous punctures; median sulcus of first sternum present entire length of sternum, narrow and deep on anterior third, broad and shallow on the posterior two-thirds..... *sulcatus*, new species

   Ventral transverse sector of occipital carina not extending laterally beyond point where lateral sector would join it if latter were present; vertexal impressions short, elliptical; median sulcus of first sternum absent on posterior third of sternum, of approximately same width throughout, but deep on anterior third, shallow elsewhere ..... *paxillatus*, new species

Aglyptacros eureka (Banks), new combination
(Pl. 2, Fig. 5a, b)

Glyptometopa eureka Banks, Canad. Ent., xliv, p. 202 (1912).

Type.—Female, Palmerlee, Ariz., September (Biederman) [Museum of Comparative Zoology].

The holotype of this species has been studied at our request by Dr. Richard Dow, who has kindly contributed the following notes: "*Glyptometopa eureka* Banks is a member of the genus *Aglyptacros* and is closely allied to *segredentatus* Mickel and Krombein. The unique holotype of *eureka* has been compared with the unique holotype of *segredentatus* and found to differ in the following particulars: The length is somewhat greater (12.0 mm. as against 10.5). The clypeus lacks the narrow, smooth margin, only the apical carina being impunctate. The vertexal impressions are represented by fewer, less concentrated, larger punctures. The ventral, transverse sector of the occipital carina is continuous at the midline, on either side of which is a strongly elevated, rounded lobe. It is joined to the lateral sector in an evenly rounded curve. The carina behind the transverse sector of the occipital carina is continuous at the midline and has two low, rounded prominences. It then extends diagonally, gradually approaching the lateral sector of the occipital carina lateral to the foramen. The dorsum of the propodeum has the anterior third impunctate, the remainder having fewer, more widely scattered punctures than in *segredentatus*. The large punctures of the second tergum are not arranged in rows, but irregularly distributed over the disk."

Dr. Dow also made several sketches of the ventral aspect of the occipital region of the head and the line drawings in Figure 5 were made by Mr. Cushman from Dr. Dow's sketches and under Dr. Dow's supervision the day after the type was examined.

Aglyptacros segredentatus, new species
(Pl. 1, Fig. 3; Pl. 2, Fig. 4a, b; Pl. 3, Fig. 19)

Holotype.—Female, Benson, Ariz., July 21, 1917 (J. Bequaert) running on ground in desert [Museum of Comparative Zoology].

Female.—Length 10.5 mm. Light brownish orange, the tips of the mandibles castaneous. Setae very pale glistening yellow.

Head glabrous, shining; mandibles (see generic description) setose beneath anteriorly at broadest area, and with a setose sulcus on outer surface just above ventral carina; interantennal space and narrow anterior margin of clypeus glabrous, impunctate, the two separated by a narrow area of small, contiguous punctures extending from base of one mandible to the other; scape only slightly compressed, ventral aspect thickly setose, dorsal aspect with a thin tuft of setae distally as well as sparse setae elsewhere; pedicel and first four flagellar segments with several setae on outer aspect; front with sparse, well separated punctures, most of them in a transverse area between eye margins posterior to antennal fossae, along inner and posterior eye margins, and between posterior

eye margins and curved row of punctures at postero-lateral angles of vertex; only three or four punctures on disk of front; vertexal impressions asymmetrical, irregular in shape, consisting of three or four deep, contiguous, setose punctures, the right, vertexal impression having one of the punctures distinct from the remainder; genae with a number of separated or subcontiguous punctures between terminus of curved row of punctures and base of mandibles; postgenal and hypostomal areas with numerous, shallow, subcontiguous punctures, the latter sparse along anterior, lateral margins of the proboscidal fossa and posterior to an imaginary line extending from antero-lateral angles of occipital carina to base of mandibles; ventral half of occipital carina present and complete, lateral sectors continuous with transverse sector at a right angle; transverse sector of occipital carina interrupted medially, median, free ends of carina bent anteriorly at interruption and carina strongly elevated at angle formed, thus somewhat dentiform each side of interruption; elevated edge of transverse sector of occipital carina sharp, not crenulate; a much shorter, medially interrupted, transverse carina a short distance posterior to occipital carina; remainder of area posterior to transverse sector of occipital carina weakly rugose.

Thorax glabrous, shining, length from neck to abdominal attachment almost but not quite twice width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, with a few, scattered punctures throughout, but the latter more numerous and conspicuous at anterior and lateral margins; lateral surfaces of pronotum with scattered, widely separated, shallow punctures, ventral and anterior margins slightly carinulate; suture separating dorsal surface of mesopleura from mesonotum almost obsolete, although faintly visible in certain lights; mesonotum with a few, widely separated punctures at anterior margin, and with a row of punctures at posterior margin, punctures separated by about their own diameter, otherwise impunctate; dorsal surface of mesopleura with close, subcontiguous, deep punctures; dorsum of propodeum with anterior half almost impunctate, only three or four punctures, but posterior half with a number of irregularly placed punctures, some subcontiguous, others separated, posterior margin with an irregular, transverse row of punctures; posterior face of propodeum with a narrow, dorsal, transverse area impunctate, otherwise closely, minutely punctate; lateral surfaces of propodeum almost impunctate, except subcontiguous punctures at dorsal margin; proepisterna with coarse, separated punctures, almost asperate, the broad, ventral, carinate margin impunctate, castaneous; metasternum triangular in general outline, but subcordate, each lateral half rounded posteriorly, elevated and convex, thus posterior margin broadly, deeply emarginate; surface of metasternum with small, close punctures, except posterior lobate margins, which are impunctate.

Abdomen glabrous, shining, posterior segments somewhat shagreened; anterior declivous face of first tergum minutely punctured, dorsal face with sparse, scattered punctures, except at lateral margins, where the punctures are contiguous; second tergum with some punctures on anterior portion arranged in one or two transverse rows; succeeding terga with only a few, scattered

punctures; first sternum triangular, glabrous, with a median, longitudinal sulcus present only on anterior third, lateral margins with a row of punctures, the latter much deeper and contiguous anteriorly and forming a sulcus, otherwise impunctate, except for numerous, inconspicuous micropunctures; second sternum with numerous, small, well separated punctures anteriorly, and becoming very sparse posteriorly; succeeding sterna very sparsely punctate; posterior margin of pygidial tergum bilaterally sinuate.

Male.—Unknown.

Remarks.—This and *eureka* are the only species of *Aglyptacros* with the ventral half of the occipital carina complete, that is, with the lateral sectors extending forward and continuous with the transverse sector. In this species, however, the ventral and lateral sectors meet in a distinct angle.

Aglyptacros paxillatus, new species

(Pl. 2, Fig. 6)

Holotype.—Female, La Junta, Colo., August 30, 1903 (E. A. Popenoe, Acc. No. 2181) [United States National Museum, Type No. 56213[13]].

Female.—Length 10.5 mm. Uniformly brownish orange, except antennae, which are stramineous, and the tips of the mandibles, which are castaneous. Setae pale glistening yellow.

Head glabrous, shining; mandibles (see generic description) setose beneath anteriorly at broadest area and with a setose sulcus on outer surface just above ventral carina; posterior half of interantennal space impunctate, though slightly shagreened and anterior margin of clypeus glabrous, impunctate, the two separated by a transverse, closely punctate area extending from base of one mandible to the other; scape only slightly compressed, sparsely setose, the setae somewhat thicker on ventral and dorsal aspects than on lateral ones; pedicel and first four flagellar segments with usual setae on outer aspect, although the flagellum of the type is denuded; front with sparse, well separated punctures, most of them in a transverse area between eye margins posterior to antennal fossae, and along inner and posterior eye margins; disk of front with only three or four punctures; vertexal impressions small and circular; genae with sparse, scattered punctures; hypostomal and postgenal areas anterior to occipital carina with numerous, shallow, subcontiguous punctures; lateral sectors of ventral half of occipital carina obsolete, carina not extending forward to lateral terminus of transverse sector; transverse sector of occipital carina not extending laterad of a point where the lateral sectors would join it if they were present, interrupted medially as in the preceding species, but angles near interruption not elevated; entire edge of transverse carina somwhat crenulate; area just posterior to occipital carina with an additional, transverse, shorter carina, the latter angulately produced anteriorly at median line; remainder of area posterior to transverse sector of occipital carina weakly rugoso-punctate.

13 The type has been deposited in the United States National Museum through the kindness of Professor R. H. Painter of the Kansas State Agricultural College.

Thorax glabrous, shining, its length from neck to abdominal attachment one and two-thirds times its width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, with a few, scattered punctures throughout, but punctures more numerous at lateral and anterior margins; lateral surfaces of pronotum with contiguous punctures anteriorly, separated punctures posteriorly, and carinulate at ventral margin; suture separating dorsal surface of mesopleura and the mesonotum distinct, but not conspicuous; mesonotum with subcontiguous to contiguous punctures at anterior and posterior margins, remainder impunctate, except for a few, very small, inconspicuous punctures; dorsal area of mesopleura with contiguous, coarse punctures; dorsal surface of propodeum with anterior third impunctate, posterior two-thirds with sparse, distinct, separated punctures, posterior and lateral margins marked by a row of contiguous to subcontiguous punctures; posterior surface of propodeum with a narrow, transverse, dorsal area impunctate and slightly shagreened, the remainder closely, minutely punctate; lateral surfaces of propodeum impunctate, except dorsal marginal area, which is closely, shallowly punctate; proepisterna coarsely punctate, almost asperate, except broad, ventral margin, which is impunctate and castaneous; metasternum triangular in general outline, subcordate, each lateral half posteriorly rounded, elevated and convex, thus posterior margin broadly, deeply emarginate; surface of metasternum with small, close punctures, except posterior lobate margins, which are impunctate.

Abdomen glabrous, shining, becoming delicately shagreened posteriorly; declivous, anterior surface of first tergum closely, minutely punctate, dorsal surface with subcontiguous punctures anteriorly and laterally, sparse and scattered punctures elsewhere; succeeding terga with sparse punctures; second tergum with scattered punctures on anterior portion; first sternum triangular, lateral margins with a row of punctures, anterior third of the row deep and sulcate; a median, longitudinal sulcus on anterior two-thirds of first sternum, sulcus approximately same width throughout; punctures on surface of first sternum very small, shallow, scattered and inconspicuous; second and third sterna with small, scattered punctures; succeeding sterna almost impunctate; pygidial tergum bilaterally sinuate.

Male.—Unknown.

Remarks.—Differs from the preceding species in having the lateral sectors of the occipital carina obsolete and not meeting the transverse sector of the carina, and in the latter not being conspicuously elevated each side of the median interruption; also differs in the form of the vertexal impressions, the distinctness of the mesonotal-mesopleural suture, the greater length of the median sulcus on the first sternum, and in its slightly darker color.

Aglyptacros sulcatus, new species

(Pl. 2, Figs. 7 and 12)

Holotype.—Female, Valentine, Tex., July 12, 1938 (D. W. Craik) [University of Kansas].

Female.—Length 12.0 mm. Uniformly castaneous. Setae pale glistening yellow.

Head glabrous, shining; mandibles (see generic description) somewhat darker at tip, setose beneath anteriorly at broadest area, with a setose sulcus on outer surface just above ventral carina, and with a sparse tuft of setae on outer surface at base; interantennal space and anterior margin of clypeus glabrous, impunctate, the two separated by a narrow, transverse, closely punctate area extending from base of one mandible to the other; scape only slightly compressed, ventral and dorsal aspects sparsely setose, two lateral surfaces with a few, scattered setae; pedicel and first three flagellar segments with a few setae on outer surface, fourth apparently without setae; front with sparse, separated or subcontiguous punctures, most of them in a transverse area between eye margins just posterior to antennal fossae, and along inner and posterior margins of eyes; disk of front with only three or four widely scattered punctures; vertexal impressions linear, asymmetrical, consisting of contiguous, setose punctures, the right one with one or two of the posterior punctures separated from the rest; anterior third of genae with separated to subcontiguous punctures, remainder of genae impunctate, except three or four punctures laterad of curved row of setose punctures on postero-lateral angles; hypostomal and postgenal areas closely, shallowly punctate, punctures closest at margin of proboscidal fossa and gradually becoming more separated and then sparse outwardly; lateral sectors of ventral half of occipital carina obsolete, not extending forward and joining transverse sector; transverse sector of carina long, extending distinctly laterad of point where the lateral sector would join it if the lateral sector were present; transverse sector also interrupted medially, but carina not elevated each side of interruption, free edge of carina somewhat crenulate; a short transverse carina immediately posterior to transverse sector of occipital carina, the former produced anteriorly at middle forming a short, distinct V; remainder of area posterior to transverse sector coarsely rugoso-reticulate.

Thorax glabrous, shining, its length from neck to abdominal attachment one and two-thirds times its width at and including mesopleural ridges; pronotal disk with its median length approximately half its greatest width, with sparse, scattered punctures throughout, but more numerous and closer at lateral and anterior margins; lateral surfaces of pronotum weakly shagreened and with contiguous and subcontiguous punctures, except the median, posterior area almost impunctate, ventral margin somewhat carinulate; mesopleural-mesonotal suture distinct; mesonotum with subcontiguous punctures at anterior and posterior margins, and with a few, fine punctures scattered laterally on disk; dorsal area of mesopleura with contiguous, coarse punctures; anterior third of dorsum of propodeum impunctate, remainder with sparse, separated or subcontiguous punctures, except a row of contiguous punctures at posterior and lateral margins; posterior face of propodeum with a narrow, transverse, impunctate area at dorsal margin, otherwise closely, minutely punctate; lateral surfaces of propodeum impunctate for the most part, except the dorsal,

marginal area, which is contiguously punctate; proepisterna coarsely punctate, subasperate, except the broad, ventral margins, which are impunctate, the sharp, carinate margin much darker than elsewhere, almost black; metasternum triangular in general outline, but the posterior margin roundly, deeply emarginate, forming rounded, elevated, convex, lateral lobes, and thus the whole more or less subcordate; surface of metasternum, especially posterior lateral lobes, contiguously punctate almost to posterior margin.

Abdomen glabrous, shining, becoming more and more shagreened from front to rear; declivous, anterior face of first tergum minutely punctate, dorsal surface with large punctures, contiguous and subcontiguous at anterior and lateral margins, but becoming sparser and more separated towards posterior margin of tergum; second tergum with scattered, smaller punctures; succeeding terga practically impunctate; first sternum triangular, lateral margins marked by a row of contiguous punctures, anterior fourth of row very deep, broad and sulcate; median, longitudinal sulcus of first sternum present for its entire length, anterior third narrow and deep, posterior two-thirds broad and shallow; surface of first sternum minutely punctate, punctures sparse and scattered on anterior two-thirds, much more numerous on posterior third; second sternum with a few, scattered punctures; succeeding sterna with fewer and fewer punctures; posterior margin of pygidial tergum bilaterally sinuate.

Male.—Unknown; possibly *Brachycistis castanea* Cresson.

Remarks.—Differs from the preceding three species in the long, transverse sector of the occipital carina, which extends laterad each side much beyond the point where the lateral sector would join it; in the presence of a median sulcus the entire length of the first sternum; in the linear vertexal impressions; and in its uniformly darker color.

UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, MINN.
AND
BUREAU OF ENTOMOLOGY AND
PLANT QUARANTINE,
U. S. DEPT. OF AGRICULTURE
WASHINGTON, D. C.

PLATE 1

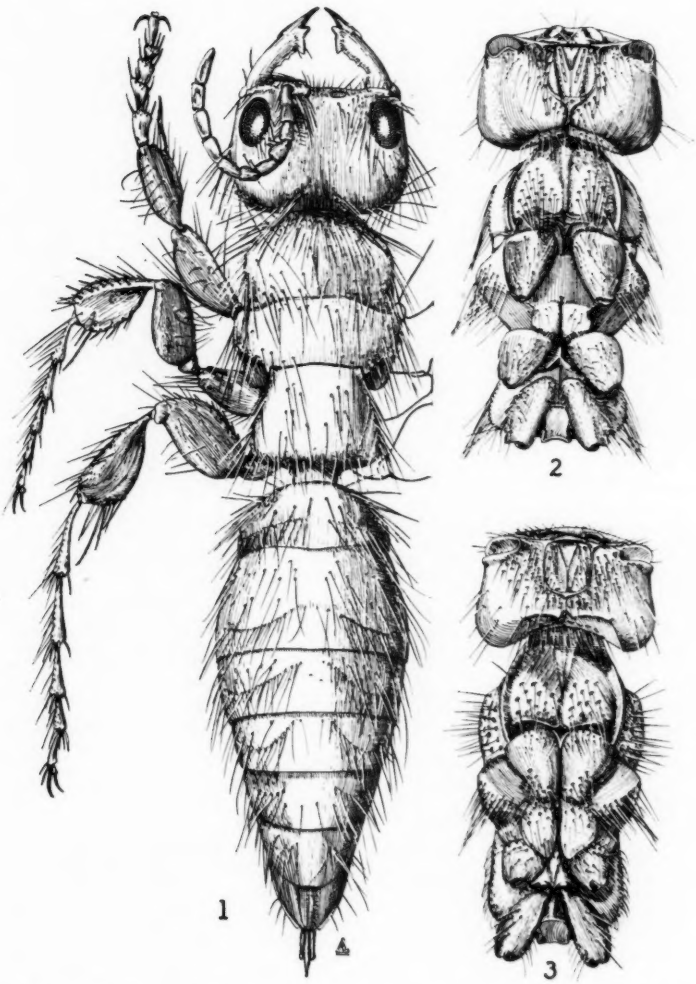


Fig. 1. Dorsal view of *Glyptometopa francisca*, n. sp. Fig. 2. Ventral view of head and thorax of *Glyptometopa francisca*, n. sp. Fig. 3. Ventral view of head and thorax of *Aglyptacros segredentatus*, n. sp. (Drawings by Mr. Arthur D. Cushman, Bureau of Entomology and Plant Quarantine.)

PLATE 2

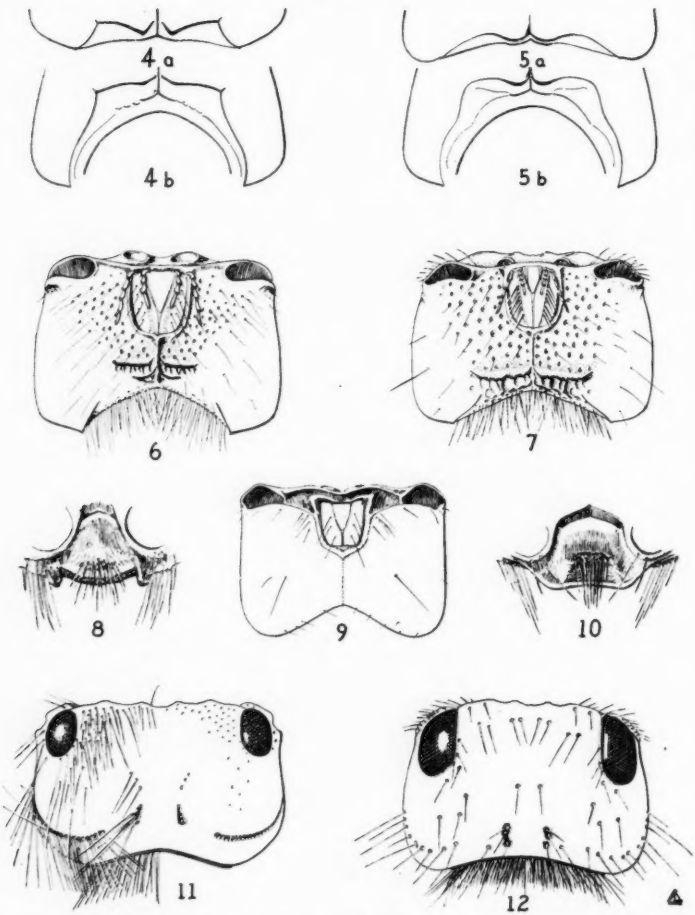
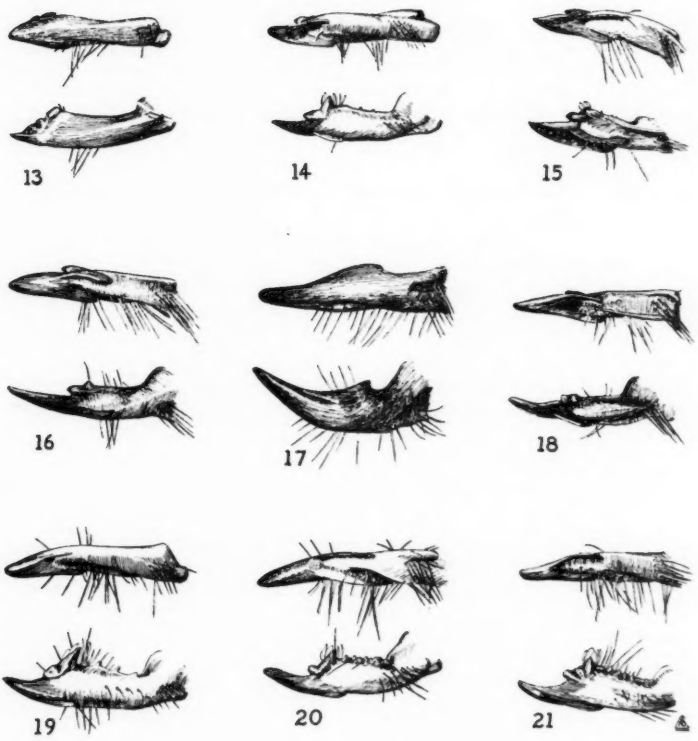


Fig. 4. Ventral view of occipital region of *Aglyptacros segredentatus*, n. sp. A, as seen from in front of occipital carina; B, as seen from behind occipital carina. Fig. 5. Ventral view of occipital region of *Aglyptacros eureka* (Banks). A, B, as in Fig. 4. Fig. 6. Ventral view of head of *Aglyptacros paxillatus*, n. sp. Fig. 7. Ventral view of head of *Aglyptacros sulcatus*, n. sp. Fig. 8. Median third of clypeus of *Glyptacros ashmeadi*, n. sp. Fig. 9. Ventral view of head of *Stilbopogon alutacea*, n. sp. Fig. 10. Median third of clypeus of *Glyptacros angustior*, n. sp. Fig. 11. Dorsal view of head of *Aulacros latior*, n. sp. Fig. 12. Dorsal view of head of *Aglyptacros sulcatus*, n. sp. (Drawings by Mr. Arthur D. Cushman, Bureau of Entomology and Plant Quarantine.)

PLATE 3



Mandibles of *Glyptometopa* and allies—lateral view at top, dorsal view at bottom of each set of figures. Fig. 13. *Glyptometopa convergens*, n. sp. Fig. 14. *Glyptometopa francisca*, n. sp. Fig. 15. *Stilbopogon alulacea*, n. sp. Fig. 16. *Glyptacros angustior*, n. sp. Fig. 17. *Astigmometopa emarginata*, n. sp. Fig. 18. *Xeroglypta egregia*, n. sp. Fig. 19. *Aglyptacros segredentatus*, n. sp. Fig. 20. *Aulacros latior*, n. sp. Fig. 21. *Eurycros furtivus*, n. sp. (Drawings by Mr. Arthur D. Cushman, Bureau of Entomology and and Plant Quarantine.)

The Genus Neocoelidia in the United States (Homoptera: Cicadellidae)

Dorothy J. Knull

The genus *Neocoelidia* was described by Gillette and Baker in 1895 (Hem. Colo., Agr. Exp. Sta., p. 103) with *N. tumidifrons* designated as the genotype. Up to the present time nineteen species and one variety have been recognized.

This paper is a result of a study of the Collection of The Ohio State University, which includes specimens from Herbert Osborn Collection and those collected by D. J. and J. N. Knull; the Entomological Collection of The University of Kansas, including some paratypes, loaned by Dr. R. H. Beamer; Collections from the U. S. National Museum, including the E. D. Ball Collection, and specimens compared with the types by Dr. P. W. Oman, loaned by Dr. Oman; and specimens from the Collection of Prof. Dwight M. DeLong. In addition, collections in the care of Dr. Nathan Banks, Harvard University; Dr. E. S. Ross, California Academy of Sciences; Mr. E. T. Cresson, Jr., and Mr. J. A. G. Rehn, Philadelphia Academy of Natural Sciences; and Department of Entomology, Agricultural College, Fort Collins, Colo., were made accessible.

After a study of all this material seventeen species and one variety are considered as valid, one species is placed in synonymy, and one is reduced to varietal status. Four species and two subspecies are described as new.

Ordinarily in recent years there has been a tendency to base identification of leafhoppers to a considerable extent upon characters of the inner male genitalia. However, in this genus, the species are readily separable on the basis of external characters. The inner male genitalia were studied, and although possessing distinctive characters, were found to be unreliable criteria for separation of several of the closely related species. Their general structure has been discussed by P. W. Oman (Jour. Kans. Ent. Soc. 4:62-28, 1931), and has not been further described here, except incidentally in connection with specific descriptions.

The original description of the genus based upon the robust short *N. tumidifrons,* was amended by Baker (Can. Ent. 30:289, 1898) to include the longer, more narrow form *"resembling Thamnotettix"* common in the southwest. In addition, there is a very characteristic round black spot on apex of head in all but two species, and all but three have a black spot in either scutellar angle, at least in the male.

KEY TO SPECIES OF NEOCOELIDIA

1. Head lacking apical black spot 2
   With black spot 5

2. Robust; usually black spots in basal scutellar angles, at least in male ..... *tumidifrons* and var. *villapennis*
   Slender, unicolorous 3
3. Elytra yellowish, semihyaline 4
   Elytra white, subopaque ..... *pallida blanda* n. subp.
4. Head sub-conical at apex ..... *pallida*
   Head angulate ..... *pallida acuta* n. subsp.
5. Lacking median dorsal dark stripe 6
   With stripe 15
6. Some elytral reticulation 7
   No reticulation 9
7. Reticulation profuse; small ..... *reticulata*
   Reticulation sparse 8
8. Anterior two-thirds of clavus reticulate ..... *diabola* n. sp.
   Slight reticulation on corium ..... *romantica* n. sp.
9. Less than 5 mm. long 10
   Over 5.25 mm. long 14
10. Vertex with distinct pattern 11
    Vertex lacking pattern; 3-3.5 mm. long ..... *lactipennis*
11. Milky to dirty white in color 12
    Yellowish to tawny 13
12. Head subconical ..... *ramona*
    Head broadly, bluntly rounded ..... *candida*
13. Robust; from Arizona and Utah ..... *balli* n. sp.
    Slender; from California ..... *orovila*
14. Slender ..... *obscura*
    Robust; elytral veins brown ..... *distincta*
15. Stripe continuous from vertex to apex of clavus 16
    Stripe not continuous 21
16. Stripe on vertex laterally lobed 17
    Stripe laterally sinuate or straight 18
17. Lobes about equal in size ..... *barretti*
    Basal lobes extending dorso-cephalad ..... *beameri*
18. Stripe broad 19
    Stripe narrow 20
19. Head greatly produced; stripe sinuately edged ..... *pulchella*
    Head blunt; stripe straight-sided ..... *fuscovittata*
20. Small; stripe laterally sinuate ..... *texana*
    Large; stripe straight-edged ..... *grandiosa* n. sp.
21. Stripe distinctly margined on elytra 22
    Stripe indistinctly margined 23
22. Stripe divided anteriorly by median pale area ..... *tripunctata*
    Stripe evident on elytra only, where it is twice angulately broadened ..... *compta*
23. Radial veins of wings showing through elytra; yellowish to orange ..... *lineata*
    Paler, greenish; wing veins not distinctly seen through elytra ..... *lineata* var. *penelineata*

NEOCOELIDIA TUMIDIFRONS G. & B.

Neocoelidia tumidifrons, Gillette & Baker, Hemiptera Colorado, Agr. Exp. Sta., p. 104, 1895.

Distinguished readily by its robust form, and the absence of a black apical spot on head.

Common east of the Rocky Mts., occurring as far north as Manitoba and south through Florida; west into the Dakotas, Colorado, New Mexico and Texas. Records show that it is taken more commonly in July and August,

although the southern records indicate it occurs throughout the year. In Gillespie Co., Texas, late in June, it was swept in all stages of development from a low, bushy composite, *Heterotheca* Cass.

Neocoelidia tumidifrons var. *vittapennis*, DeLong, D.M., Jour. N. Y. Ent. Soc. **32**:66-7, 1924.

"Elytra marked with brown vittae which follow for the most part the wing venation. A stripe just inside the costal margin, a rather broad stripe along the commisural line and the veins of the wings brown, often margined with brown. Sometimes the tips of the elytra are dark brown, smoky." (DeLong)

The variety was described from Florida specimens. Darker coloring seems to be more prevalent in southern specimens.

NEOCOELIDIA PALLIDA Bak.

Neocoelidia pallida, Baker, C. F., Can. Ent. **30**:290, 1898.

As Baker mentioned Tucson, Arizona first the pale yellowish unicolorous form with its strongly produced head, found almost exclusively in Arizona and Mexico, is regarded as the species. In some males the apical cells of the elytra become hyaline, and occasionally traces of a pair of obscure parallel longitudinal vittae are found on the vertex.

Collection dates range from February to October and the species seems to be well distributed in the southern mountainous region of Arizona.

That several forms have for some time been included with *pallida* has long been recognized by various authors. As examination of inner male genitalia does not give a distinct basis for separation of these other forms, two are described here as subspecies.

Neocoelidia pallida blanda n. subsp.

Opaque chalky white, structurally resembling the species, but without hyaline apical cells. A Texas form taken from purple sage.

Length: male, 4.25 mm.; female, 5 mm.

In The Ohio State University Collection:—holotype male, Val Verde Co., Texas, May 6, 1941; allotype and paratype, Kinney Co., Texas, May 5, 1941; and paratypes, Uvalde Co., Texas, May 3, 1941, all collected by D. J. and J. N. Knull. In the University of Kansas Collection, paratypes, collected by R. H. Beamer, in Texas:—Concan, July 6, 1936, Big sage; 65 mi. so. Marathon, July 10, 1938; Corrizo Sprgs., July 23, 1928; San Ygnacio, July 23, 1938. In the U. S. National Museum Collection:—paratypes, Laredo, Texas, June 3, 1933, P. W. Oman; Alpine, Texas, August 8, 1936, E. D. Ball; Brownsville, Texas, Jan. 3, 1932, E. D. Ball; Comstock, Texas, August 9 and Sept. 1, 1936, E. D. Ball; George West, Texas, July 4, 1936, R. H. Beamer; Marathon, Texas, August 8, 1936, E. D. Ball; and N. Laredo, Mexico, August 31, 1936, E. D. Ball.

Neocoelidia pallida acuta n. subsp.

Distinguished from the species by its acutely angulate produced head which is almost twice as long at middle as is pronotum, and narrow. The female is greenish white, male with more of a yellowish tinge.

Length: male, 4.5 mm.; female, 5 mm.

This was probably included in Baker's description as those taken from Palm Springs, Calif., on July 12th by Prof. Morse.

In The Ohio State University Collection:—Male holotype, allotype and paratype, Palm Springs, Calif., May 19, 1941, D. J. & J. N. Knull; paratypes, Palm Springs, Calif., Feb. 8 and Palm Canyon, March 3, H. Osborn. University of Kansas Collection:— paratypes, by R. H. Beamer, El Centro, Calif., July 24, 1938; Indio, Calif., June 29, 1933; Palm City, Calif., July 27, 1938; Bunkerville, Nev., Aug. 8, 1936; and four specimens placed tentatively in this subspecies from Zion N.P., Utah, August 13, 1929, by R. H. Beamer and P. W. Oman. The U.S. National Museum:—paratypes, Ft. Yuma, Ariz., No. 201, Hubbard; Yuma, Ariz., from March 29 to Nov. 2, E. D. Ball; Calexico, Calif., June 18, 1909, E. D. Ball; Caliente, Calif., July 12, 1929, E. D. Ball; Imperial, Calif., June 18, 1909, E. D. Ball; Indio, Calif., June 19, 1909, E. D. Ball; Littlefield, Ariz., on *Pluchea sericea* (Nutt.) Cov., E. W. Davis; Overton, Nev., E. W. Davis; Palm Canyon, Calif., June 4, 1935, P. W. Oman; and "Cala. 2313," C. F. Baker Coll.

NEOCOELIDIA RETICULATA Ball

Neocoelidia reticulata, Ball, E. D., Ent. News **20**:167, 1909.

Unique for its dense elytral reticulation, and its small size. Length: male, 3.7 mm.; female, 4.3 mm.

Rare. In the University of Kansas Collection, collected in California by R. H. Beamer:—Carlsbad, August 6, 1935; Palm City, August 7, 1935; and San Diego, August 7, 1935: and in the U.S. National Museum a small series collected by E. D. Ball at Tia Juana, Mexico, August 3, 1912. Tia Juana, California, is mentioned in Ball's description as the type locality.

Neocoelidia diabola n. sp.

Creamy white with coarse, light brown, elytral reticulation.

Female. Head bluntly conical, vertex broad, as long as wide, disc flat, faint carina separating it from front, front tumid; pronotum two-thirds as long at middle as vertex, anterior margin rounded, broadly, angulately excavated behind, finely granulose, lateral margins broadly rounding; scutellum as long as vertex. Elytra broad, compressed at apex, venation distinct, coarsely reticulate except in apical third of clavus and in apical cells. Last ventral segment four times as long as preceding, almost truncate on posterior margin with small, sharp, median indentation.

Male. Pronotum a little longer in proportion to vertex than in female.

Plates joined three-fifths longer than basal width, triangular, exceeded a little by pygofer apex, only slightly compressed on apical third, apices rounded.

Color. Creamy white, head with small round black spot at apex, vertex yellowish with a brown discal design consisting of a pair of narrow median lines starting even with ocelli and extending almost to posterior margin. These lines have short lateral projections at either end and just below middle at right angles to them. In some specimens this pattern is broken. Two broad light brown stripes continue across pronotum and into basal angles of scutellum, area beneath eyes slightly darkened. Two shining black minute ovals, one in each basal angle of scutellum in mid-outer lateral margin. Elytra creamy subhyaline with light brown veins and reticulations, apical and marginal veins pale; eyes brown; below pale. Face with pale median stripe flanked by light brown sides. Tip of beak, tarsal claws and in male, portion of pygofer showing below plates, dark.

Length: female, 5 mm.; male, 4.75 mm.

The Ohio State University Collection: Holotype, female, Devil's Canyon, Arizona, August 25, 1938, from oak, by D. J. and J. N. Knull; and the United States National Museum:—allotype, Glenn Oaks, Ariz., October 7, 1929, E. D. Ball; paratypes, Mt. Graham, Ariz., August 27, 1937, E. D. Ball; Yarnell Hts., July 21, 1929, and October 8, 1929, E. D. Ball; and Wilboit, Ariz., Dec. 15, 1939, Christenson.

Neocoelidia romantica n. sp.

Resembling *N. diabola* n. sp., but smaller, darker, and with sparse reticulation confined to corium.

Male. Head bluntly conical, vertex as broad between eyes as median length, indistinct traces of marginal carina; pronotum slightly more than a third shorter than median length of vertex, evenly rounded in front, broadly, angulately excavated behind. Elytra broad, reaching beyond apex of abdomen, appressed apically, venation distinct, sparse reticulation confined to corium.

Cream colored washed with orange on vertex and scutellum; head with black apical spot, vertex with white narrow median line from apex to base, on either side a broader brown band with lateral projections, anterior extending obliquely to margin, middle parallel to fore, reaching margin above eyes, and basal short, knob-like, darker brown at outer extremity. Eyes brown, ocelli nearer to eyes than to apex; pronotum with pair of diverging median stripes bordered outside by pale, and beneath eyes embrowned; scutellum with apex, portion between basal angles and outer margin of basal angles, including minute round black spot, dirty white; basal angles creamy orange. Elytra creamy semi-hyaline, nervures and reticulations dark brown, except apically, where they are pale. Below cream to light brown with lateral margins of front marked by numerous confluent brown arcs; thorax beneath beak, and venter of abdominal segments dark brown, genital area pale.

Female. Coloring much lighter than in male, and veins less distinctly

embrowned. Last ventral segment 3/5 as long as broad, truncate posteriorly with faintly sinuate margin and small, sharp median notch; shorter at middle than at sides.

Male plates together longer than combined basal width, triangularly produced, narrowed on apical third, with apices truncate, not quite covering dark brown pygofer apex.

Length: male, 3 mm.; female, 4.3 mm.

Holotype, male, San Diego, Calif., August 7, 1935, R. H. Beamer, allotype and one male paratype, same date, all in the University of Kansas Collection.

Neocoelidia lactipennis (Van D.)

Jassus lactipennis, Van Duzee, E. P., Ent. Am. **6**:49-51, 1890.

The smallest known United States *Neocoelidia*, oval, short, thick and milky white with brown elytral nervures, paler at apex; vertex about twice as long as pronotum at middle. It is apparently quite uncommon.

In the University of Kansas Collection:—a large series, Yucca Grove (17 mi. east of Baker), Calif., August 7, 1936, R. H. Beamer. The U. S. National Museum:—two females, Los Angeles Co., Calif., Coquillet (date corresponding to that of type specimens; labeled *lactipennis* by Van Duzee and labels folded on pin); Las Vegas, Nev., October 18, 1927, David E. Fox and "Ut.-Nev., August 30, 1930" in the Ball Collection.

NEOCOELIDIA RAMONA Ball

Neocoelidia ramona, Ball, E. D., Ent. News **27**:206, 1916.

Smaller, more robust, and darker than *orovila*. The dark dorsum showing through the milky subhyaline elytra, especially in the males, gives a dark cast to the insect which is peculiar to this species.

Length: male, 3:75 mm.; female, 4.5 mm.

Less common than *orovila* and confined to California with a wide distribution in that State.

NEOCOELIDIA CANDIDA Ball

Neocoelidia candida, Ball, E. D., Ent. News **20**:166-7, 1909.

The common, white, broad-headed, sage species found in western Texas, Colorado, New Mexico, Utah, Arizona, Nevada and California.

Neocoelidia balli n. sp.

Similar in coloring and general appearance to *N. romantica* n. sp., but more robust, and lacking reticulation. Recognized as undescribed by E. D. Ball and P. W. Oman.

Male. Head somewhat conical, vertex not as long as breadth between eyes, margins indicated, apex bluntly pointed; pronotum a little over half as long as vertex at middle, anterior margin evenly rounded, posterior broader, angulately

excavated; elytra broad at base, meeting in sharp point at apex, venation distinct, outer apical cells very short; male plates united, longer than combined width at base, gradually tapering to slightly diverging apices which do not quite cover darkened pygofer apices below.

Female. Last ventral segment about square but appearing longer than broad as it is raised roof-like at posterior margin, and slightly excavated medially. Some trace of median longitudinal keel on posterior half.

Color. Rich, creamy white washed with yellow and tawny; a round black spot at apex of head and an oval one on mid-outer margin of each scutellar basal angle. Pale median longitudinal stripe on vertex, pronotum and scutellum, either side on vertex a narrow brown stripe with three evenly spaced lateral projections not reaching eyes. Eyes black, remainder of vertex tawny; front pale medially with many short brown indistinct lateral arcs. Pronotum with pair of median brown vittae broadening toward base, also darkened beneath eyes; basal angles and apex of scutellum tawny; elytra whitish semi-hyaline, veins fuscous, discs of cells washed with bright yellow, apical cells fumose; below creamy yellow, tinged with tawny, ovipositor pale orange.

Length: male, 4 mm.; female, 4.5 mm.

In the U.S. National Museum:—male holotype and nine paratypes, both sexes, Granite Dell, Ariz., October 6, 1929, E. D. Ball; and allotype, St. George, Utah, October 30, 1935. Light trap.

Named for Dr. E. D. Ball who collected all but one of the type series, and in whose collection it was labeled undescribed.

NEOCOELIDIA OROVILA Ball

Neocoelidia orovila, Ball, E. D. Ent. News **27**:206-7, 1916.

Slender, cream-colored, the male more tawny; resembling *balli* n. sp. in coloring, but much less robust; vertex one-fifth longer than pronotum at middle.

Length: male 4.3 mm.; female, 4.5-5 mm.

Collected in California, more commonly in the southern part. Beamer reports collecting it on manzanita, *Arctostaphylos canescens* Eastw. and *A. glauca* Lindl.

NEOCOELIDIA OBSCURA Baker

Neocoelidia obscura, Baker, C. F., Can. Ent. **30**:289-90, 1898.

Neocoelidia pentagona, Ball, E. D., Ent. News **27**:207, 1918. (See Oman, P. W., Jour. Kans. Ent. Soc. **4**: p. 68, 1931).

Neocoelidia triunata, Ball, E. D., Ent. News **27**:207-8, 1916. (New synonymy).

The common southwestern member of this genus from manzanita, *Arctostaphylos* Adans., although it was swept from soapberry, *Sapindus marginatus* Walld. in the Davis Mts., Texas. A large straw-colored insect with a pentagonal vertex, often rather faintly marked with orange to reddish vittae.

Taken abundantly in Texas, New Mexico, Arizona, Utah, California and Oregon.

As is true in *N. distincta* Oman, nymphs are often marked with a blood-

red pattern, and in freshly emerged adults this coloring may persist for a time. Study of a large series of specimens from many localities, including examination of inner male genitalia, indicates that Ball's *N. triunata* is but the freshly emerged *obscura*. A series of *N. triunata* from Logan, Utah, the type locality, including one compared with the type by P. W. Oman, was available for study. Dr. Ball's label indicated *triunata* as a variety of *obscura*.

NEOCOELIDIA DISTINCTA Oman

Neocoelidia distincta, Oman, P. W., Jour. Kans. Ent. Soc. **4**:67-8, 1931.

A large, robust green species with all of elytral veins distinctly brown. Described from males. The females are considerably larger and more robust than the males, length 6.5-7 mm., and the elytral veins are less distinct than in the males.

Nymphs have a scarlet line extending from apex of vertex to apex of abdomen, and also on lateral margins of abdomen. Scarlet streaks appear near the "knee" on outer surfaces of femora and tibiae. Newly emerged adults which retain this bright coloring have a very striking appearance.

Common on cat's-claws, *Acacia greggii* Gray, where it has often been beaten from dead branches. It has been taken in the Big Bend region of Texas, southern New Mexico and Arizona, and Nacazara, Mexico.

NEOCOELIDIA BARRETTI Bak.

Neocoelidia barretti, Baker, C. F. Can. Ent. **30**:291, 1898.

Three black edged, outwardly extended lobes on each side from dark median dorsal stripe of vertex, central larger, distinguish this species considered by Baker as "the most striking N.A. species of the genus."

A specimen compared with the type by P. W. Oman, in the collection of the U.S. National Museum, was collected from banana debris at Brownsville, Texas, ex Mexico, November 13, 1936, by J. M. Singleton. Two specimens, male and female, Los Amates, Guatemala, Feb. 25, 1905, are in the Osborn Collection of The Ohio State University.

NEOCOELIDIA BEAMERI Oman

Neocoelidia beameri, Oman, P. W., Jour. Kans. Ent. Soc. **4**:63-65, 1931.

Dorsal stripe black with basal pair of vertexal lobes "extending laterocephalad in horn-like protuberances.... This species may be separated from *N. barretti* Baker by its smaller size and the fact that the dorsal vitta is much wider on the posterior margin of the pronotum than on the anterior margin and has the black spots on the scutellum within the lateral margins of the median vitta" (Oman).

Dr. Beamer kindly loaned two paratypes for study from Cameron Co., Texas, August 3, 1928, E. I. and R. H. Beamer. The Ohio State University Collection contains a small series collected at Brownsville, Texas, August 8,

1937, and May 25, 1939, D. J. and J. N. Knull; and the U.S. National Museum a specimen from Brownsville, Texas, January 4, 1932, E. D. Ball.

NEOCOELIDIA PULCHELLA Ball

Neocoelidia pullohella (apparent misspelling), Ball, E. D., Ent. News **20**:168, 1909.

Large and robust with a strongly produced, pointed head, and with a continuous broad median brown stripe, margined narrowly with black from base of vertex. Stripe varies in width as follows: "four regular oval enlargements on vertex, from which it regularly broadens to the base of the scutellum, then slightly narrows to the elytra, on the elytra there are three slightly angular enlargements increasing in size posteriorly. There is an irregular black spot just outside the apex of the clavus on either side from which the smoky stripe (from apex of clavus to apex of elytra) takes its origin" (Ball).

This ornate species seems to be limited in its distribution to the southern part of California. Beamer has taken it on *Rhus integrifolia* B. & W.

NEOCOELIDIA FUSCOVITTATA Oman

Neocoelidia fuscovittata, Oman, P. W., Jour. Kans. Ent. Soc. **4**:65-6, 1931.

Blunt-headed; apex of head very obtuse. A yellowish species with a dark brown median longitudinal stripe arising on disk of vertex, broadening from black apical spot, to cover all except small outer portion of basal angles of scutellum. At apex of pale area and partly within dorsal stripe, a small black spot. Much darker than *N. linea* Baker and somewhat more robust. The last ventral segment of female is produced, longest at middle, sinuate and slightly notched at middle of posterior margin.

Described from localities in Arizona and New Mexico. It has been taken also in South Dakota, Nebraska, Colorado and Texas from July to October.

NEOCOELIDIA TEXANA Oman

Neocoelidia texana, Oman, P. W., Jour. Kans. Ent. Soc. **4**:62-3, 1931.

Distinguished by shape of vertexal markings and dorsal stripe as follows: "Apex of vertex with a small black spot, often continuous with the brown median vitta which arises on the disk of the vertex and extends to tip of elytra, indistinctly margined beyond clavus. Dorsal stripe narrow on vertex, widening gradually to scutellum, slightly sinuate and not at all laterally lobed on vertex, pronotum or scutellum but expanded laterally on middle and apex of clavus and becoming still wider on the corium outside the tip of clavus" (Oman).

Through the courtesy of Dr. Beamer, paratypes from Hidalgo Co., Texas, July 30, 1928, R. H. Beamer, were expanded. The Ohio State University Collection contains one specimen from Brownsville, Texas; and there is one in the Collection of Dr. D. M. DeLong collected at Brownsville, Texas, May 8, 1935, by J. N. Knull.

Neocoelidia grandiosa n. sp.

Large, with a very narrow median dorsal stripe, confluent to apex of clavus except on scutellum. Near *N. tripunctata* Ball. Head conical, vertex as long as wide, with lateral margins slightly carinate; front broad and tumid. Elytra exceeding apex of abdomen by one and one-third mm., broad, veins except claval and inner apical, obscure, indicated by rows of small, widely spaced punctures, three inner apical cells formed. Female segment three times as long as preceding, sharply but shallowly excavated at middle, forming evenly rounded lateral lobes; ovipositor exceeding pygofer. Male plates twice as long as basal width, gradually narrowing to apical third where there is rapid narrowing and in apical third together form a single narrow finger-like process which is a trifle shorter than pygofer.

Color: Pale yellowish white, a narrow median cinnamon brown stripe extends from the small round black point at apex of head to apex of clavus, and a smoky, less distinct area continues it to apex of elytra. Brown stripe occupies median 1/3 of vertex, almost parallel margined, broadens regularly to base of scutellum where it is separated on basal two-thirds by a narrow pale longitudinal stripe, narrows slightly on elytra at apex of scutellum and broadens distinctly at apex of clavus to fill area between vein and suture. A darker brown irregular area on clavus just anterior to apex of clavus forms base for smoky continuation of stripe through inner apical area of elytra, darker along appendix. Small black point is included in stripe at outer edge either side of scutellum just above median impressed transverse line. Stripe more or less distinctly margined by milky white area on pronotum and base of elytra, remainder of elytra semihyaline.

Length: female, 6.3 mm.; male, 5.7 mm.

In The Ohio State University Collection:—holotype, female, Tumacacori Mts., Arizona, August 21, 1940, D. J. and J. N. Knull; the University of Kansas Collection:—paratypes, Santa Rita Mts., Arizona, July 17, 1932, June 12, 1933, R. H. Beamer; and Ruby, Arizona, July 22, 1938, R. H. Beamer; The U.S. National Museum: allotype and paratypes, Santa Rita Mts., Arizona, June 27, 1933, P. W. Oman; and Tucson, Arizona, May 12, 1929, E. D. Ball.

This species has been recognized for some time as undescribed by P. W. Oman and was so indicated on both National Museum and University of Kansas specimens which he had labeled.

NEOCOELIDIA TRIPUNCTATA Ball

Neocoelidia tripunctata, Ball, E. D., Ent. News **20**:168, 1909.

Resembling *N. grandiosa* n. sp., but with dorsal stripe separated medially on vertex and pronotum too.

Described from one female. Male: vertex wider than long, head bluntly conical; background creamy yellow, a large round black spot at apex. Vertex and pronotum with pair of faint brown stripes growing darker posteriorly, but

slightly separated medially, and margined exteriorly with milky white. Scutellum pale with basal angles smoky yellow with a shining black point on outer margin either side above median impressed transverse line. Elytra with narrow common sutural stripe, which thickens, filling apex of clavus where it ends. Veins broadly embrowned, which is not true in female. Apex of elytra suffused with smoky yellow. Veins of apex pale and not as distinct; basal cells subhyaline white; below cream, genital area embrowned except for yellow basal area on plates. Plates together as long as broad, triangular, apex blunt, pygofer lobes exceeding them by one-third. Last ventral segment of female long, squarely rounded at apex with shallow median emargination.

Length: male, 5 mm.; female, 5.25 mm.

Comparatively rare. The Ohio State University Collection contains:—small series, Davis Mts., Texas, May 9, 1941, from oak, D. J. and J. N. Knull; Chisos Mts., Texas, June 9, 1939, D. J. and J. N. Knull. The University of Kansas Collection:—Santa Rita Mts., Arizona, July 5, 8,000 ft., F. H. Snow; and August 18, 1935, R. H. Beamer; and Davis Mts., Texas, July 12, 1938, R. H. Beamer. U.S. National Museum:—Huachuca Mts., Arizona, July 30, 1935, E. D. Ball (compared with type by Oman); and Santa Rita Mts., Arizona, June 16, 1933, P. W. Oman. D. M. DeLong's Collection:—Huachuca Mts., Arizona, June 9, 1935, J. N. Knull.

NEOCOELIDIA COMPTA Ball

Neocoelidia compta, Ball, E. D., Ent. News **20**:167-8, 1909.

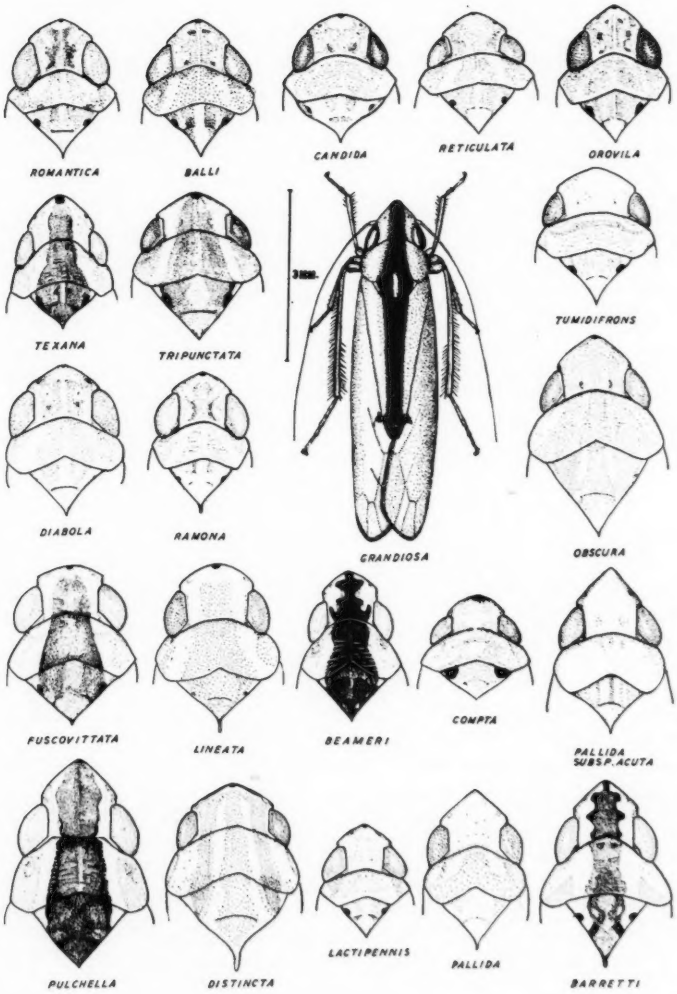
Ornate, with large shining black spots in basal scutellar angles against posterior margin of pronotum; elytra with brown median dorsal stripe twice triangulately extended out on clavus. Coloring decidedly darker in males. Often stripe but faintly indicated in females but darkened outer points on clavus always discernible.

Host, mallow, *Sphaeralcea* St. Hill spp.; found swarming in Oak Creek Canyon, August 1, 1938. It was described from Mesilla, New Mexico, and has been taken in Brewster Co., Texas; Juarez, Mexico; Oak Creek Canyon, Congress Junction, Glenn Oaks, Granite Dell, Phoenix, Tucson, Prescott, and Chiricahua Mts., Arizona; and Kanab, Utah, in June, July and August.

NEOCOELIDIA LINEATA Baker

Neocoelidia lineata, Baker, C. F., Can. Ent. **30**:289, 1898.

Head broadly, obtusely rounded; dorsal stripe indefinitely indicated from dark apical spot to apex of elytra, often lacking anteriorly. Elytra subhyaline, somewhat darker along sutural margin and at apex. Tergum black, visible through elytra. Veins of wings, except second sector, strong and dark, showing through elytra. In males these dark veins are usually especially strong and the ground color tends to be more orange. A common species in the Pacific Coast States, which is often swept in large numbers from pine, although this is probably not the host.


ROMANTICA
BALLI
CANDIDA
RETICULATA
OROVILA
TEXANA
TRIPUNCTATA
3 MM.
TUMIDIFRONS
DIABOLA
RAMONA
GRANDIOSA
OBSCURA
FUSCOVITTATA
LINEATA
BEAMERI
COMPTA
PALLIDA SUBSP. ACUTA
PULCHELLA
DISTINCTA
LACTIPENNIS
PALLIDA
BARRETTI

Specimens collected in British Columbia, Washington, Idaho, Oregon and California from June to October, have been studied. It is often difficult to distinguish between *N. lineata* and the following form.

NEOCOELIDIA LINEATA var. PENELINEATA Oman

Neocoelidia penelineata, Oman, P. W., Jour. Kans. Ent. Soc. **4**:66-7, 1931.

In his description, Oman states "This species may be distinguished from *N. lineata* by the fact that the hind wings do not have radius darkened and that it is decidedly more greenish in color."

In series of *N. lineata* there often occur lighter specimens which answer the description of *N. penelineata*. As examination of characters of the inner male genitalia of specimens from a number of localities, and of varying color intensities, showed no specific variation, this form is here given varietal rather than specific status.

All figures drawn to same scale except *N. grandiosa* in which the scale is indicated.

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Descriptions of Certain North American Phidippus (Araneae)

Elizabeth B. Bryant

Possibly it is because the Salticidae (Attidae) spin no snares, but wander about through the vegetation in search of their prey, that the sexes are so rarely found together. In any event, it is due to this fact that the determination of the alternate member for a pair of any of the Phidippus is as unsatisfactory as in other genera of the family.

The Peckhams, active collectors themselves, received much material from widely separated regions and made a study of the Salticidae their life-work. In spite of this, of the wide vision of the field thus afforded, even they found females of this family very difficult to place. In their final "Revision of the Attidae of North America" one finds many species which remain to this day known from one sex alone.

The Collection of Araneae at the Museum of Comparative Zoology is particularly rich in material for study of the Salticidae. It has all of the Banks and Peckhams Collections and the Emerton types as well. Recently considerable new material received has made possible the identification of the other sex of several Phidippus and has added one new species, from North Carolina, where it was found in a pitcher plant by W. T. Davis.

A description of this new species and the completed description of six other species form the subject of the present paper which is prefaced by a review of the genotype *Phidippus variegatus* (Lucas).

All specimens and types are in the Collection of the Museum of Comparative Zoology, at Cambridge, Massachusetts.

Phidippus C. L. Koch, 1846

Of the Salticidae found in North America, some of the largest of the so-called Jumping Spiders belong to the genus *Phidippus*. In general, both males and females are above median size; the cephalothorax is high and massive, with rounded sides. The first row of eyes is recurved, and the second row is much nearer the first row than it is to the third; the eyes of the third row are usually elevated on a low tubercle and placed a little in from the margin. Some species are remarkable by reason of conspicuous tufts of curled hair which occupy the ocular area; in others, short hairs form a crest between the first and third eye rows. The mandibles are large, have a single tooth on the lower margin of the fang groove and are often iridescent, green or violet. The abdomen, clothed with hairs, has a color pattern of iridescent scales, in many species this differs strikingly between the sexes; as if to further complicate matters, the abdominal markings, in the same sex and species are subject to

great variation of color and pattern, for example, the entire abdomen may be brilliant with red or yellow scales, or again, in the same species two parallel dark stripes may appear on the posterior half. The white basal band however, for any given species is of constant length.

The male palps, of which there are three types, furnish competent criteria for division of this genus into groups. The most usual form is that of the genotype, *P. variegatus* (Lucas). In this type, the embolus terminates in a recurved hook; *P. incertus* (Peck.) exhibits an example of the second type, the embolus ending in a broad, undulate process, the rounded tip of which bends away from the palp; the third type may be best seen perhaps in specimens of *P. purpuratus* Keys., where the embolus is a slender chitinized spine that protrudes from the inner margin of a broad unchitinized lobe.

The arrangement of spines on the legs furnishes another useful generic character. The first tibia has three pairs of spines, 2-2-2, the distal pair opposite, the median and basal pairs not so.

Phidippus variegatus (Lucas)

Salticus variegatus Lucas, Ann. Soc. Ent. France, 1833, **2**:478, pl. 18, Fig. A, 1.
Figs. 1, 5, 18

Male. Length, 13.0 mm., ceph. 6.0 mm. long, 5.5 mm. wide, abd. 7.0 mm.

Cephalothorax reddish-brown, ocular area darker, no eye tufts, but a row of long hairs over anterior eye row, sides with a large semi-circular spot of white scales, high and massive, nearly as wide as long, with sides rounded, thoracic groove short, in a depression between dorsal eyes; *eyes*, anterior row recurved, a.m.e. separated by more than a line, a.l.e. little more than half the diameter of a.m.e and separated from them by more than a radius of a.l.e., small eyes one-third nearer to anterior eye row than to the dorsal eyes, p.l.e. subequal with a.l.e., raised on a low tubercle, not on extreme margin of the carapace; *quadrangle* wider behind than in front; *clypeus* without hairs or scales, a few long bristles on margin, less than a radius of a.m.e.; *mandibles*, a brilliant iridescent green, vertical, without hairs or scales, sides parallel, narrowed at distal third, with a knob-like prominence above fang, as in *P. audax* (Hentz); *maxillae* with upper outer corner ending in a hook, curved forward; *abdomen* oval, pale basal band fading out along the sides before the middle, reddish-brown, with a pair of oblique spots that tend to fuse about the middle, followed by a pair of diagonal bars halfway between the central pale spot and the spinnerets, entire abdomen clothed with many long stiff dark bristles, venter gray; *legs*, 1-4-2-3, I pair heaviest, femur dark, with a thick ventral fringe of black hairs, patella pale with a white fringe, tibia with a thick ventral black brush, patella nearly as long as tibia, (75:90), metatarsus with ventral fringe, dark on distal half, and white on basal half, spines, patella, o, tibia, ventral, 2-2-2, small and difficult to distinguish because of the dark brush, metatarsus, ventral, 2-2; II pair, same as I pair but smaller, spines, patella,

o, tibia, ventral, 2 distal, lr, lr, metatarsus, ventral, 2-2; *palpus*, less than length of cephalothorax, femur slender and curved, tibia shorter than patella, tibial apophysis a slender black spur that curves inward and forward, cybium clothed with coarse black hairs, tip flattened and flattened area not surrounded with spicules, bulb extending onto tibia, in a cone opposite apophysis, embolus at tip, a small, slender, curved hook.

Female. Length, 13.5 mm., ceph. 5.5 mm. long, 5.5 mm. wide, abd. 9.0 mm.

Coloring of female agrees with that of the male except that the scales of the white spots on the sides extend forward and cover the clypeus; *eyes* and *mandibles* same as in the male; *maxillae* with upper outer corner not prolonged into a hook; *abdomen*, color and pattern same as in male; *epigynum*, chitinized area longer than wide, opening at anterior end, oblique and separated by a narrow septum at base, posterior half quite convex, the usual median opening triangular.

♂ ♀ Alabama; Mobile County, (Loding).

Phidippus variegatus (Lucas) was described in 1833 from both males and females in the Paris Museum Collection, said to have come from New Orleans. The description is in Latin and very brief; this is followed by a longer one in French. The very high broad cephalothorax is mentioned with the two large spots of white scales on the sides, mandibles iridescent green and transversely roughened, dark abdomen with a median white spot divided by a narrow line; the fringes of black and white hairs beneath the anterior legs are minutely described and at the end of the description the length is given as 4 lignes (= 10.0 mm.), adding that when the legs are extended the spread would be about 7 or 8 lignes. The colored figure shows a high and very broad cephalothorax with large white spots on the sides, and a pair of small, white spots about the middle of the abdomen.

In 1846, C. L. Koch redescribed and figured this species in "Die Arachniden," 13, p. 125, fig. 1186. He evidently had another species, as he gives the length as 6 lignes and his figure is of a much larger and heavier species which has a median spot on the abdomen followed by a pair of white transverse bars, a pair of large white spots above the spinnerets and a pair of diagonal lateral lines about the middle of the abdomen. This may be the species described and figured by Hentz in 1845, as *Attus otiosus*.

As the lateral spots on the cephalothorax are of rather small white scales, easily brushed off, leaving no scar or trace, they may be and often are lacking, especially towards the end of life. The spots on the abdomen are also of white scales, but these are much larger, and usually a few scales remain, even where the abdomen is shrunken from age.

P. variegatus has been confused with *P. audex* (Hentz) and *P. otiosus* (Hentz) but it can be distinguished from *P. audax* which also has large iridescent mandibles with a lobe above the fang groove, by the large lateral white spots on the cephalothorax, and from *P. otiosus* by the lack of eye tufts and also the lack of heavy white scales on the basal half of the mandibles.

PHIDIPPUS COMATUS Peckham. Trans. Wisc. Acad. Sci., 1901, 13, :291, pl. 23, fig. 8.

Figs. 2, 4

Male. Length, 8.0 mm., ceph. 4.2 mm. long, 3.2 mm. wide, abd. 4.0 mm.

Cephalothorax dark brown, with a band of white scales over anterior eye row that connects with a submarginal stripe which does not reach the posterior margin, a large spot of white scales between dorsal eyes, a fringe of long dark bristles above anterior row of eyes, one tuft of long curved bristles below small eyes, lateral margins much rounded so that cephalothorax appears almost as wide as long, thoracic groove short; *eyes*, anterior row recurved, a.m.e almost touching, a.l.e. separated from a.m.e by more than a radius of a.l.e, small eyes one-third nearer first than to third row, dorsal eyes not on extreme margin of carapace, raised on a strong tubercle; *quadrangle* wider behind than in front; *clypeus* retreating, less than a radius of a.m.e., lower half covered with reddish-orange scales and a fringe of white hairs on margin, below each a.l.e. a transverse V of red scales; *mandibles* brown, with a faint greenish iridescence, sparsely covered with long white hairs, two teeth on superior margin, one tooth on inferior; *maxillae* dark, upper outer corner in a sharp tooth; *sternum* brown; *abdomen* oval, dorsum flat, dark brown with a basal band of white scales that extends on sides half way to spinnerets, a basal spear mark of reddish-brown scales that reaches middle, followed by a median spot of white scales bifid at tip, with two pairs of lateral bars that do not reach the middle on posterior half, anterior pair longer, entire dorsum with many long black bristles and scattered iridescent scales, venter brown, with darker lateral stripes and a shorter median dark stripe, sides with white scales; *legs*, 1-4-2-3, I pair modified, brown, with patella and tibia darker at tips, femur greatly swollen, laterally compressed, distal quarter constricted with white scales on dorsal surface, ventral surface dark brown, convex and shining, near tip, two retrolateral tufts or curls of long incurving bristles, basal tuft longer, prolateral surface covered with a brush of darker hairs and soft long white hairs, patella with a ventral fringe of soft white hairs, almost as long as tibia, tibia with a scant ventral fringe of long white hairs, white scales on dorsal surface, spines, patella, prolateral, 1, tibia, dorsal, o, lateral, o, ventral, 2-2-2, metatarsus, ventral, 2-2, distal and median, other legs brown with dark bands at tips of patellae and tibiae, patellae, II, III and IV with paired lateral spines, III and IV tibiae with no dorsal, basal spine; *palpus* not as long as cephalothorax, femur pale, retrolateral fringe of long white hairs on femur, patella and tibia, tibial apaphysis short, at right angles to apex, dark, with an incurving tip, embolus a stout, dark spine, very similar to *P. putnami*.

Allotype ♂ Nevada; Reno, 17 August 1940, (La Rivers).

Phidippus comatus was described by the Peckhams from three females collected at Las Vegas, New Mexico, all with most of the hairs and scales rubbed off. In a small collection of jumping spiders from Reno, Nevada, a freshly moulted female was found. It was identified by the epigynum. The year previous, a male was collected from the same locality that had similar

markings, with the secondary characters found only in the male. The two undoubtedly belong together. The species belongs to the section of the genus with *coccineus, femoratus, putnami* and *octopunctatus*. The males have the first femur modified, either enlarged or fringed, and *femoratus* and *putnami* have distinctive crests of short hairs about the eyes; *femoratus* is the only one that has a curl of stiff hairs or bristles at the distal end of the first femur and *comatus* has two curls; *octopunctatus* was described from a male and probably even when first seen by the Peckhams, was rubbed and lacking most of the hairs and scales. Today, it is very much broken, but enough remains to show that the cephalothorax had a white spot in the eye area and that the first femur was enlarged, laterally compressed with a dorsal crest and a ventral fringe of short hairs. The palpus is very similar to *comatus* but the tibial apophysis is a continuation of the tibia, not at right angle to the apex, and the embolus is more slender.

Phidippus dorsalis spec. nov.

Figs. 6, 9, 15

Male. Length, 9.4 mm., ceph. 4.8 mm. long, 4.2 mm. wide, abd. 5.0 mm. *Cephalothorax* reddish-brown, with no white scales and very few short dark hairs, slightly darker about the eyes, a few long bristles posterior to small eyes and one or two below small eyes, suggestive of eye tufts, carapace high, sides much rounded, thoracic groove short in a shallow depression; *eyes*, anterior row strongly recurved, a.m.e. separated by little over a line, a.l.e. less than a radius of a.m.e. and separated from them by fully a diameter of a.l.e., small eyes nearer first than to third row, dorsal eyes not on margin and slightly larger than a.l.e. and raised on low tubercles; *quadrangle* slightly wider behind than in front; *clypeus* less than radius of a.m.e., retreating with no hairs or scales; *mandibles* flat in front, basal half brown, distal half with a greenish iridescence, no hairs or scales, narrowed at tip with a slight lobe over fang, fang groove oblique, one large tooth on inferior margin; *labium* longer than wide; *maxillae* with upper outer corner prolonged in a short hook; *abdomen* oval, mottled with dark and light brown, with no distinct pattern, pale basal band short and very narrow, entire dorsum covered with very long hairs, venter dark and much shrunken; *legs*, 1-4-2-3, I pair enlarged, dark, with fringes of dark hairs, femur with a ventral fringe and a scant dorsal crest, patella, ventral fringe, distal half dark, basal half of long white hairs, tibia with a thick fringe of short hairs covering row of spines on inner side, metatarsus with a scant ventral fringe, spines, patella, o, tibia, ventral, 2-2-2, metatarsus, ventral, 2-2, II pair, smaller than I pair and fringes the same but not as heavy, spines, patella, o, tibia, ventral, 2 distal, lr, lr, metatarsus, ventral, 2-2; *palpus* shorter than cephalothorax, dark, no white scales but a scant fringe of long dark hairs on femur, tibia shorter than patella, tibial apophysis a short incurved spur, cybium flattened at tip but area not surrounded by bristles, bulb very large, covering tibia, embolus a short, curved hook at tip very similar to *P. insolens* (Hentz).

Female. Length, 12.2 mm., ceph. 5.7 mm. long, 4.5 mm. wide, abd. 8.1 mm.

Cephalothorax bright reddish-brown, with more short dark hairs than in the male, and several long dark bristles in eye area, few white scales and longer hairs above anterior eye row, upper eye tuft fairly heavy, carapace high and sides rounded as in male, thoracic groove short, in a shallow depression between dorsal eyes; *eyes* same as in male; *clypeus* higher than in male, about equals diameter of a.m.e, thickly covered with white scales that extend on sides as far as small eyes; *mandibles,* vertical, basal quarter covered with white scales, remainder of a brownish-green iridescence, no lobe over fang as in the male; *maxillae* with tips rounded; *abdomen* brown, with an elongated mark of white scales from muscles spots to beyond the middle, scales at posterior end iridescent, a posterior pair of short transverse lateral bars, basal band narrow, extending only a short distance on sides, entire dorsum with many long dark bristles, venter with a median darkened area, margined with pale dots; *legs,* 1-2-4-3, I pair enlarged, fringes and spines as in male, metatarsus with a narrow basal band of white scales; palpi with a narrow ring of white scales at ends of each joint; *epigynum,* chitinized area longer than wide, anterior pair of openings elongate-oval, separated by a narrow septum and followed by two pairs of dark sacs beneath the skin, posterior opening an equilateral triangle, area between openings is strongly convex.

Holotype ♂ North Carolina; Southern Pines, June 1920, (Davis).
Allotype ♀ North Carolina; Southern Pines, June 1920, (Davis).
Paratypes ♀ North Carolina; Southern Pines, June 1920, (Davis).

Phidippus dorsalis differs from the typical species by the very high cephalothorax with very rounded sides, and the dorsal eyes well back from the margin, so that the quadrangle is only slightly wider behind than in front. The male has no scales on the cephalothorax and the female has white scales on the clypeus and basal half of the mandibles. In both, the abdomen has many long hairs and the fringes on the legs is the same. The epigynum is very similar to the figure given by the Peckhams for *Phidippus insolens* (Hentz), except the anterior openings are oval instead of round and the posterior opening is triangular, not wider than long. In the male, the palpus has a very large bulb which covers the tibia. In the female the rings of white scales on each joint of the palpi are very conspicuous.

PHIDIPPUS INCERTUS Peckham. Trans. Wisc. Acad. Sci., 1901, 13 :292, pl. 24, fig. 1.

Figs. 7, 8, 13, 16

Female. Length, 10.5 mm., ceph. 5.0 mm., abd. 6.3 mm.

Cephalothorax dark brown, two pairs of eye tufts, the dorsal pair heavier, a band of white hairs over anterior eye row, two large white spots in ocular area near base of dorsal eye tufts and a median spot over thoracic groove, thoracic slope with white hairs but not thick enough to call a band, moderately high, thoracic groove short, sides slightly rounded; *eyes,* anterior row recurved, a.m.e. separated by less than a radius, a.l.e. about a radius of a.m.e. and separ-

ated from them by more than a diameter of a.l.e., small eyes one-third nearer first than third row, dorsal eyes slightly larger than a.l.e, not on extreme margin of carapace; *quadrangle* wider behind than in front; *clypeus* very narrow, retreating, less than half a radius of a.m.e, thickly covered with white hairs; *mandibles* dark brown, no white hairs, slightly iridescent at tip, geniculate; *labium* dark brown longer than wide; *maxillae* dark brown, once and a half times as long as labium; *abdomen*, spider has oviposited, oval, and flattened, dark brown, covered with white hairs in diagonal lines, and very long dark hairs, or bristles, a rather wide basal band that barely reaches middle of sides, a pair of oblique pale spots over muscle spots, followed by a larger pair of spots, also oblique that are about the middle, on the sides four pairs of diagonal bars, the longest midway between the median spots and spinnerets, venter pale, with a broad median dark stripe from fold to spinnerets; *legs* 1-2-4-3, reddish-brown, broad dark bands at distal ends of patellae and tibiae, with scattered white hairs and white scales, I pair largest, many long white hairs on ventral side of femur, patella and tibia, but not thick enough to be called a fringe, spines, patella, o, tibia, ventral, 2-2-2, spines short, metatarsus, ventral, 2-2, II pair, several long white ventral hairs on patella, tibia and metatarsus, spines, patella, o, tibia, 1 prolateral near tip, ventral, 2 distal, lr, lr, metatarsus, ventral, 2-2; *epigynum*, chitinized area longer than wide, openings oblique, separated by more than long diameter, slightly posterior and nearer median line, a pair of smaller diagonal marks, notch above fold a simple curve.

Male. Length, 9.6 mm., ceph. 4.1 mm., abd. 5.6 mm.

Cephalothorax dark reddish-brown, with the same white hairs found in the female and the two pairs of eye tufts; *eyes* same as in female; *clypeus* very narrow, with white hairs and scales and a fringe of white hairs on the margin; *mandibles*, basal half covered with white scales, distal quarter hairless, a dark iridescent green; *maxillae* with upper outer corner pointed; *abdomen* oval, thickly covered with short white hairs and much longer bristles, so that pattern is very indistinct, however, two pairs of pale spots can be traced, anterior pair over muscle spots, the larger pair about the middle, a lateral pair of transverse bars between the median spots and on the posterior half two pairs of shorter transverse bars, venter with a wide median dark stripe from fold to spinnerets, bordered on sides by a row of white dots and all covered with long white hairs; *legs*, 1-4-2-3, brown with distal joints paler, femora with white ventral hairs, I pair slightly enlarged, femur laterally flattened, ventral side with a prolateral crest of white hairs and a retrolateral fringe of long white hairs, patella and tibia with a very scant ventral fringe, spines, patella, o, tibia, ventral, 2-2-2, metatarsus, ventral, 2-2, II pair, patella, o, tibia, ventral, 2, distal, lr, lr, metatarsus ventral 2-2; *palpus* shorter than cephalothorax, dark brown with many short hairs, very few long white hairs on cybium, cybium flattened at tip and area outlined by a circle of short, dark spicules, tibia shorter than patella, tibial apophysis dark, broad, with ventral corner prolonged in a curving hook, (see figure), bulb extends on tibia, embolus a broad, thin undulating dark piece at tip.

Holotype ♀ Texas; Austin, (Peckham Coll.)

Allotype ♂ Arkansas; Berryville, Goat Mountain, 2 September 1938, (Wilton). ♀ Arkansas; Berryville, 4 May 1939, (Wilton).

Phidippus incertus was described by Peckham in 1901. The type is in the Museum of Comparative Zoölogy Collection and is labelled Austin, Texas. By some unfortunate blunder, the figures of the dorsum and the epigynum was drawn from a specimen of *mystaceus* Hentz, and Peckham seemingly drew up the description from the figures, rather than the specimen and no locality was published. In 1909, in the "Attidae of North America," *incertus* was placed as a synonym of *mystaceus* and the figures were used for that species. According to the recognized rules, the name is carried by the specimen, irrespective of description or figure.

Phidippus incertus belongs to the section of the genus, of which *mystaceus* is probably the best known. All have very hairy abdomens and the pattern is obscured by the long hairs. The cephalic markings are apparently the same in both male and female of the same species. The palpi are curiously alike. All have the tip of the cymbium flattened and the area is surrounded by a row of black spicules, the embolus is always a broad flat undulating piece at the tip. The specific differences is in the apophyses. The epigna show greater variation. In *mystaceus* the openings are pear-shaped, with a heavy dark sac below each opening; *pruinosus* has small widely separated transverse openings; *hirsutus* has angular openings that meet in the median line. *Mystaceus* probably is not common north of Maryland and is known from both male and female; *pruinosus* is known only from the female types from Austin, Texas; *hirsutus* is much smaller than the others, and is known from both male and female from Ohio.

The two specimens from Berryville, Arkansas, were found at different seasons, the male in September and the female in May. They are undoubtedly the same species. Other species of *Phidippus* are adult at different seasons. *Phidippus otiosus* (Hentz), a very common species in the south, has the same habit. The males are found in the fall, and the females winter over under bark and spin the cocoons in the spring.

PHIDIPPUS HIRSUTUS Barrows. Ohio
Journ. Sci., 1919, 19 :358, pl. 15, fig. 6.
Fig. 3

Male. Length, 9.0 mm.

Cephalothorax dark brown, darker in the eye area and on margins, moderately high, sides gently rounded, two pairs of well defined eye tufts and a third pair of a few long curved bristles near the median line, three patches of yellow scales form a transverse line slightly anterior to dorsal eyes and posterior to the third pair of eye tufts, many long bristles posterior to anterior eye row, few very small white scales below lateral eyes, thoracic groove short in a shallow depression; *eyes*, anterior row recurved so that when seen in front,

upper margins of a.m.e. and lower margins of a.l.e. form a straight line, a.l.e. little over a radius of a.m.e. and separated from a.m.e. by less than a radius of a.m.e., small eyes nearer a.l.e. than to p.l.e. and directly anterior to the largest tuft, dorsal eyes not on extreme margin of carapace, on tubercles and larger than a.l.e.; *quadrangle* wider behind than in front; *clypeus* narrow, less than a radius of a.m.e., with a few white hairs; *mandibles* vertical, dark brown, basal portion with many long, white hairs, distal half an iridescent green; *labium* dark brown, longer than wide; *maxillae* only little longer than labium, upper outer corner prolonged in a distinct point; *sternum* dark brown, long, narrow, IV coxae touching; *abdomen* oval, dorsum flat, covered with short white hairs and many long dark bristles, many long white hairs about the lateral margins, so that abdomen has a hoary appearance, pattern very vague, but a pair of diagonal pale spots can be seen anterior to the muscle spots, followed by a larger pale spot and very indistinct cross bars at tip, venter infuscate, with many long white hairs on lateral margin; *legs*, 1-4-2-3, brown, I pair enlarged, femur flattened laterally, white hairs on ventral and retrolateral sides and a prolateral fringe of longer white hairs at distal end, patella with dorsal white scales and a prolateral and retrolateral fringe of long white hairs, tibia with many dorsal and lateral white scales and a scant ventral fringe of long white hairs, metatarsus with white scales and a scant ventral fringe, spines, femur, at tip, 2 small prolateral spines, patella, o, tibia, ventral, 2-2-2, stout, heavy, with a curved tip, metatarsus, ventral, 2-2, II pair, paler than I pair, with scant ventral fringe on tibia and metatarsus, spines, patella, o, tibia, ventral, 2-2-1r, metatarsus, ventral, 2-2, III and IV tibiae, no dorsal, basal spine, patellae, lateral, 1-1; *palpus*, shorter than cephalothorax, brown, all joints with many white hairs, that are much longer on cymbium, tip of cymbium flattened and area surrounded by a circle of dark spicules, patella slightly longer than tibia, tibial apophysis black, pressed close to cymbium, truncate, with lower corner prolonged in an incurved hook, upper corner with a short point, embolus at tip, a broad thin, black piece curved from the plane of the palpus.

♂ Connecticut; New Haven, 30 September 1877, fence, (Emerton).

This species has a wide distribution but it has never been collected in large numbers. The type is from Ohio and it has been found as far south as Georgia.

Phidippus princeps (Peckham)

Attus princeps Peckham, 1883, p. 18, pl. 2, Fig. 14, ♀.

Phidippus brunneus Emerton, Trans. Conn. Acad., 1891, **8**:225, pl. 16, Fig. 2, ♀; ibid., 1909, **14**:224, pl. 11, Fig. 1, ♂.

The original description of *Phidippus princeps* is indefinite and would agree with several species. The type, a unique female, has oviposited, so the abdomen is slightly shrunken but the epigynum is very distinct. It agrees in all features with the type of *Phidippus brunneus* Emerton. The spines of the I tibia are from a raised base, spines of the II tibia, ventral, 2 distal, lr, lr, retrolateral, 1. The epigynum has a long narrow septum with pale elongate openings on each side.

The type of *princeps* is from Pennsylvania and the two female types of *brunneus* are from Waltham, Massachusetts, collected June 2, 1890. The species has a wide distribution but nowhere is abundant. In the collection there are specimens from Center Harbor, New Hampshire, and south to Newbern, North Carolina, and west to Iowa.

Phidippus putnami (Peckham)

Attus putnami Peckham, 1883, p. 1, pl. 1, Fig. 1.
Fig. 17

Female. Length, 9.5 mm., ceph. 4.6 mm., abd. 4.7 mm.

Cephalothorax reddish-mahogany-brown, with a few white scales above lateral margin, a triangle of white scales covering thoracic groove and a short line of white scales below and between second and third rows of eyes, line not as long or as sharply defined as in male, three pairs of curls or tufts of curved bristles in a line across the ocular area, a median pair, a second pair in line with lateral eyes and behind second row of eyes, and the third pair below the white line, no wide band of white hairs posterior to first row of eyes as found in male; *clypeus* covered with white scales and a scant fringe of long white hairs on margin; *mandibles* reddish-brown, thinly covered with white hairs, distal half iridescent green; *maxillae* dark brown, no lobe on upper outer corner; *abdomen* grayish-brown, thickly covered with short gray scales and longer dark bristles, narrow basal band that extends about one-third length of the abdomen, a triangular white spot in middle as in male and two pairs of narrow white cross bars on posterior half, venter with a distinct median black spot from fold to near spinnerets with a wide lateral border of white; *legs*, 1-4-2-3, brown with scattered white scales, I pair slightly enlarged, femur laterally flattened with prolateral surface covered with soft white hairs, distal ends of patella, tibia and metatarsus darker, spines, patella, prolateral, 1, tibia, ventral, 2-2-2, metatarsus, ventral, 2-2, II pair, not enlarged, spines, patella, o, tibia, ventral, 2-2-1r, metatarsus, ventral, 2-2; *epigynum*, area longer than wide, anterior third filled with a large pair of oval openings, separated by a narrow septum, area posterior slightly convex, posterior opening a simple curve, as figured.

Holotype ♂ Iowa, Peckham Coll.

Allotype ♀ Arkansas; Berryville, summer 1939, (Wilton).

Peckham described *putnami* in 1883, from a male collected in Iowa. Since then males have been taken in many eastern localities. In the summer of 1939, Miss Wilton mated a pair found at Berryville, Akansas, and the female is described above. It differs in several points from the male. The male has no eye tufts but crests of hair betwen the lateral eyes. Both have a short line of white hairs below the second and third eye rows.

The epigynum of *putnami* is very similar to *Phidippus farneus* (Peck.) from Texas, known only from the type. In this species, the epigynum is narrowed at the anterior end and the ocular area lacks the eye tufts.

PHIDIPPUS RAUTERBERGII Peckham. Trans. Wisc. Acad. Sci., 1888, 7 :22, pl. 1, fig. 8, pl. 2, fig. 8.
Figs. 10, 14

Male. Length, 8.5 mm., ceph. 4.0 mm., abd. 4.5 mm.

Cephalothorax bright mahogany-red, with a wide lateral stripe of white hairs which starts at the anterior margin and spreads behind dorsal eyes on thoracic slope, a crescent of white hairs between dorsal eyes and a fringe of white hairs and longer black bristles above anterior eyes, thoracic groove in a faint median depression; *eyes,* anterior row recurved, a.m.e. separated by little more than a line, a.l.e. separated from a.m.e. by almost a diameter of a.l.e., small eyes one-third nearer a.l.e. than to p.l.e., dorsal eyes raised, not on extreme margin of carapace and larger than a.l.e.; *quadrangle* of eyes wider behind than in front; *clypeus* bright orange-red, with no hairs, less than a radius of a.m.e.; *mandibles* vertical, flat, lower half thickly covered with white hairs and scales; *labium* longer than wide; *maxillae* dark brown, upper outer corner prolonged in a long hook; *abdomen* reddish-brown, with a basal band of white hairs that ends before the middle, a median pale spot and three cross bars on posterior half that do not reach the median line, first opposite central pale spot, venter with a dark spot from fold to near spinnerets, margined with white scales; *legs,* 1-2-4-3, I pair enlarged, brown, all joints with scattered white scales, femur flattened laterally with prolateral surface covered with long, soft dark hairs, patella and tibia with lateral fringes of dark hairs, heavier on prolateral side, metatarsus with prolateral fringe of long hairs, spines, patella, prolateral, 1, tibia, ventral, 2-2-2, all less than diameter of the joint, metatarsus, ventral, 2-2, II pair, brown with scattered white scales, scant prolateral fringe on patella, tibia and metatarsus, spines, patella, lateral, 1-1, tibia, ventral, 2-2-1r, prolateral, 1 near tip, heavy, retrolateral, 1 small, metatarsus, ventral, 2-2; *palpus* shorter than cephalothorax, pale, cymbium almost as broad as long, with a thick prolateral fringe of very long white hairs on patella, tibia and cymbium, tibial apophysis very dark, short incurving hook, bulb almost circular, extends on tibia, cymbium much wider than palpal organ, embolus a dark, slender straight spine with tip bent.

Allotype ♂ Oklahoma; Wichita National Forest, 7 July 1928, (Newport).

The male is much smaller than the female types but both have the same crescent of white hairs between the dorsal eyes, which nearly reaches the line of small eyes, the same median white spot on the abdomen and the broad dark stripe on the venter; the lateral bars on the abdomen in the male are reduced to white spots in the female. The cymbium is much wider than is usually found in the genus, with the lateral margins broad and thin. In the only specimen seen, the cymbium is yellow with several dark dots, each bearing a long bristle.

PHIDIPPUS TEXANUS Banks. Proc. Ent. Soc. Washington, 1906, 7 :98
Figs. 11, 12

Male. Length, 10.5 mm., ceph. 5.0 mm., abd. 5.5 mm.

Cephalothorax bright reddish-brown, with many dark hairs and bristles, ocular area black, a tuft of curved bristles posterior to small eyes, and a much smaller tuft below it, cephalic portion high, a recurved depression between dorsal eyes, thoracic groove little more than a pit, no white hairs; *eyes,* anterior row recurved, a.m.e. separated by little more than a line, a.l.e. less than a radius of a.m.e. and separated from them by a diameter of a.l.e., small eyes fully one-third nearer than third row, dorsal eyes not on extreme margin of carapace, elevated and larger than a.l.e.; *quadrangle* wider behind than in front; *clypeus* reddish-brown, no hairs or scales, about a radius of a.m.e.; *mandibles* vertical, reddish-brown, distal half with a green iridescence, fang groove with two teeth on upper margin and one large tooth on lower margin; *labium* brown, longer than wide, tip narrower than base; *maxillae* brown with a thick scopula, upper outer corner ending in an upturned hook; *abdomen* oval, covered with brilliant red iridescent scales and long black bristles, no basal band, two narrow black median stripes in middle third, that unite at posterior third and continue as a wider black stripe to spinnerets, sides and venter dark with many short hairs; *legs,* 1-2-4-3, brown, with tips of tibiae and metatarsi darker, with many long dark hairs, I pair slightly enlarged, femur flattened laterally with a dorsal crest and a thick prolateral fringe of dark hairs, patella with many hairs but no fringe, tibia covered with black hairs and a heavy prolateral fringe, metatarsus and tarsus with many hairs and bristles, spines, patella, o, tibia, ventral, 2-2-2, all small and difficult to distinguish in mass of hairs, metatarsus, ventral, 2-2, distal and median, II pair, hairs as on I pair but not as heavy, spines, o, tibia, ventral, 2-2-1r, posterior pair with few spines; *palpus* almost as long as cephalothorax, pale with many short hairs, femur with two small dorsal spines, distal and median, patella longer than tibia, tibial apophysis a short, forward turned hook, bulb large, extending on tibia, embolus at tip, a broad, flat lobe, with inner margin chitinized and prolonged beyond the lobe in a short black spine, very similar to *Phidippus californicus* and *johnsoni.*

Allotype ♂ Arkansas; Berryville, from a wasp nest, summer of 1941, (Wilton).

Phidippus texanus was described from females. As the male is so unlike, it is not strange that it has not been recognized before, but during the summer of 1941, Miss Wilton found a male with females. The abdomen of the male is a brilliant red and is very striking. The male palp is very similar to *californicus* and *johnsoni,* both western species. The epigynum is very similar to *purpuratus,* a common eastern species.

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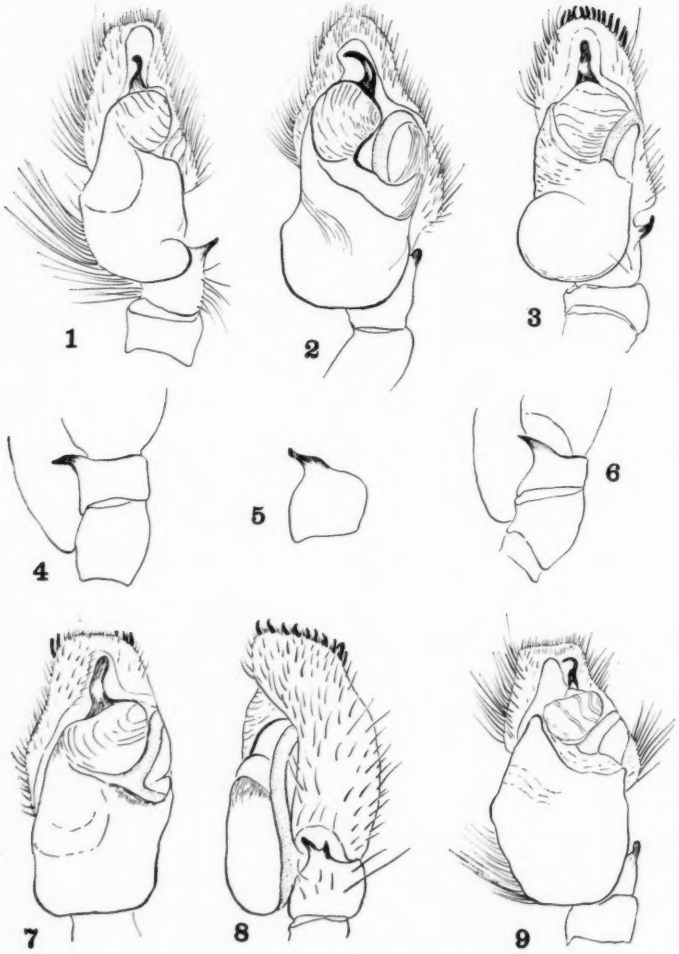

PLATE 1. Fig. 1. *P. variegatus* (Lucas), left palpus; Fig. 2. *P. comatus* Peck., left palpus; Fig. 3. *P. hirsutus* Barrows, left palpus; Fig. 4. *P. comatus* Peck., left tibial apophysis; Fig. 5. P. variegatus (Lucas), left tibial apophysis; Fig. 6. *P. dorsalis* spec. nov., left tibial apophysis; Fig. 7. *P. incertus* Peck., left palpus; Fig. 8. *P. incertus* Peck., left palpus, prolateral view; Fig. 9. *P. dorsalis* spec. nov., left palpus.

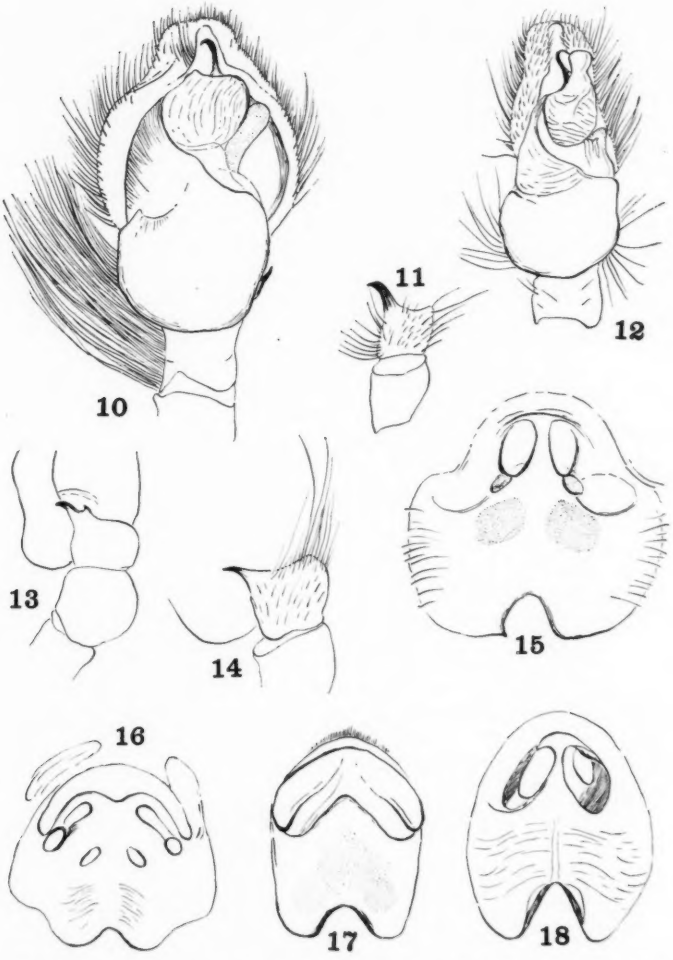

PLATE 2. Fig. 10. *P. rauterbergi* Peck. left palpus; Fig. 11. *P. texanus* Banks, tibial apophysis; Fig. 12. *P. texanus* Banks, left palpus; Fig. 13. *P. incertus* Peck. left tibial apophysis; Fig. 14. *P.. rauterbergi* Peck., left tibial apophysis; Fig. 15. *P. dorsalis* spec. nov., epigynum; Fig. 16. *P. incertus* Peck., epigynum; Fig. 17. *P. putnami* Peck., epigynum; Fig. 18. *P. variegatus* (Lucas), epigynum.

Annual Temperature and pH Fluctuations in Five Lakes of Northeastern Ohio

R. W. Dexter, E. R. Shilling, and N. J. Sanner

Introduction

The surface temperature and hydrogen ion concentration of five lakes in Portage County, Ohio, were measured weekly over a period of one year from the nineteenth of November, 1937, to that date of 1938. Temperature readings were recorded with an ordinary mercurial thermometer at a depth of about four inches, and hydrogen ion concentration was measured with La Motte colorimetric comparators. The water samples were taken at a depth of five to six inches with a reversing bottle sampler. At three of the lakes two widely separated stations were established while measurements from the other two were made at a single location. All stations were close to the shoreline, most of them being at the end of small docks. All readings were taken at approximately the same time of day for each station and within a few hours of each other. This was necessary for comparative purposes since Philip (1927) has shown that the pH of a lake may change throughout the day. Those lakes having two stations were found to be uniform in temperature and pH at both locations for each day's determination. The aim of this study was to determine in part and to compare the physical environment of the lakes and the trends of their annual fluctuation. Pearse (1939) has stated that temperature is probably the main factor in determining the hydroclimate of lakes. Shelford (1923) listed a number of reasons why the pH of bodies of water should be measured. Rawson (1939) has pointed out that while recent opinion holds that the hydrogen ion concentration is not a very important limiting factor, it may be of value as an indicator of environmental conditions.

The Lakes

Four of the lakes are situated near the Kent-Ravenna district and are within six miles of each other. The fifth is some ten miles from this group in the southwestern corner of Portage County.

1. Lake Rockwell is an impounded body of water in the Cuyahoga River. It has a surface area of 769 acres, a maximum depth of 30 feet and an average depth of some 10 feet. The bottom is chiefly clay and sand, with only a relatively small amount of vascular aquatic vegetation. However, Roach (1933) found a greater concentration of phytoplankton in this body of water than in any other of thirteen Ohio lakes which he studied. It serves as a reservoir for the City of Akron and as a state fish preserve. One station was located at the dam and another on the opposite side of the lake.

2. Brady Lake is a natural spring-fed lake with a surface of about 80 acres and a maximum depth of about 40 feet. It has a clay, sand, and gravel bottom with a fair amount of aquatic vegetation. Two stations were established on one side of the lake.

3. Lake Stafford, sometimes known as Sandy Lake, is a natural lake of 93 acres fed by Breakneck Creek. It is a shallow lake for the most part, seldom over 15 or 20 feet in depth, although at one end there is a depression of some 60 feet. It has a bottom of clay and sand with abundant aquatic vegetation in the shallow margins. One station was located at the upper end.

4. Muzzy Lake is an enlarged natural lake fed by springs and partially impounded by a small dam. It is 90 acres in size with a bottom of clay, sand, and gravel. It has a mean depth of 25 feet and a maximum depth of 60 feet. In general it is the deepest of the five lakes reported here. The outline is irregular, and aquatic vegetation is very abundant, giving rise to a swamp at one end. This lake is used as a water reservoir by the City of Ravenna. One station was maintained at the deep end.

5. Wingfoot Lake, until 1917 known as Fritch's Lake, is another enlarged natural lake which has been impounded from 318 acres to a size of 522 acres. The average depth is between 10 and 11 feet with a maximum of 16 feet. Because of its shallowness many small islands and tree trunks are present in the lake. It is a spring-fed body of water with a very irregular outline and a bottom of clay and gravel. Two stations were maintained here.

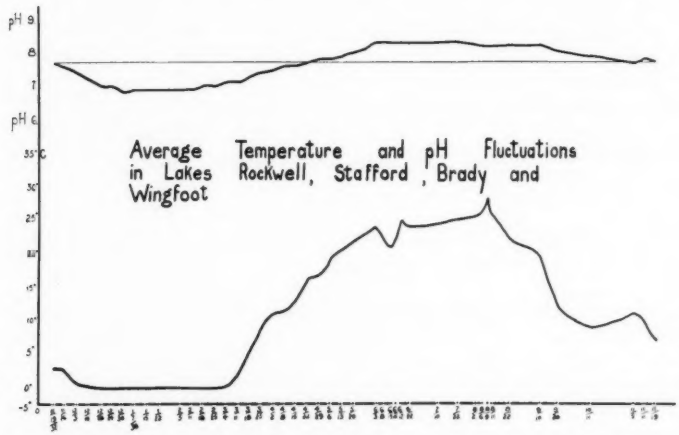

Fig. 1. Temperature and pH fluctuations in four of the five lakes studied in northeastern Ohio. II/19/37—II/19/38.

ANNUAL TEMPERATURE AND pH FLUCTUATIONS

The weekly surface temperature records of the five lakes studied here agreed closely, and the yearly average was 12.1°C. The average for each lake was within 0.7° of this, except Rockwell which averaged 10.8°C. All of the lakes responded quite readily and uniformly to weather and seasonal changes. Because the pH of Muzzy Lake did not agree with the other lakes, which were quite similar, both curves of figure 1 are based on the average of four lakes (seven stations) excluding Muzzy, even though the temperature trends were comparable for all five. Wolman and Hannan (1921) and Tressler, Wagner, and Bere (1940) give similar graphs for the fluctuations of lake temperature and hydrogen ion concentration.

The lakes were frozen over from December 3 to March 4. The maximum temperature recorded was 28°C on August 9. The four lakes of uniform conditions regarding hydron ion concentration had an annual average of pH 7.7 while that of Muzzy Lake was 7.1. With the exception of four records during the winter season, this Lake was always more acid than the others with a difference at times of as much as 1.1. Following periods of heavy rains this lake carried a large amount of sediment in the water, so that some of the discrepancies are probably due to error in reading the correct value. Juday et al (1924) reported a similar situation in Wisconsin in which four lakes had a similar surface pH value to that of Lake Mendota, but a fifth was less alkaline than the others. Welch (1935) on the other hand found great variation (4.3-9.4) in the surface pH of a number of lakes in midsummer within a radius of ten miles in the Douglas Lake region of Michigan.

By coincidence the readings taken on the first and last day, November 19, happened to fall on the yearly average for the four lakes—7.7. The average minimum of 6.8 was reached on December 30, and a return to the annual mean made by April 22. The average maximum of 8.3 was reached by June 8. These lakes fall within the range (6.5-8.5) which Welch (1935) claims is expected in most ordinary lakes of this region.

DISCUSSION

As in the findings of Wolman and Hannan for Lake Ontario and Juday (1924) for Lake Mendota, there is a correlation in the annual fluctuation of temperature and pH in the five lakes investigated. Other recent data on temperature and pH fluctuations of Ohio lakes are recorded in the papers of Tressler, Tiffany, and Spencer (1940) (summer months only), Chandler (1940), and Kraatz (1941). The pH value changes with the seasons probably because of different rates of photosynthesis in the phytoplankton and vascular plants. Photosynthetic activity during the warm months reduces the acidity of the water. Saunders (1920) has demonstrated experimentally that photosynthesis raises the pH value. Philip (1927) has shown that the daily changes are correlated with the weather and light intensity, the greatest change taking place on sunny days and at sundown.

In transplanting game fish from Lake Rockwell to some of the other lakes, a high mortality has been observed. The results of this study would indicate that the factors of temperature and hydrogen ion concentration are probably not concerned because of the close similarity of these factors throughout the year in four of the five lakes.

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A Systematic Treatment of the Genus Camassia Lindl.[1]

Frank W. Gould

Introduction

The North American genus *Camassia* of the Liliaceae comprises five species: one ranging from Pennsylvania to Texas, one widespread in the northwestern states and adjacent Canada, one coastal from Vancouver Island to California, and two endemic to the Oregon flora. All are bulbous, scapose perennials with racemose inflorescences of large, showy, blue-violet, blue, or white flowers. They grow for the most part in large and conspicuous colonies, usually in habitats that are wet at least during the growing season. The western species are of especial ethnobotanical interest because they constitute the historical "quamash" or "camas," the bulbs of which were a staple food for several tribes of western North American Indians.

Although Coville (1897) and Piper (1916) undertook treatments of the genus, neither fully distinguished the natural entities or clarified the confused taxonomy and nomenclature. The incomplete representation of *Camassia* in herbaria has made necessary extensive field study, during the course of which eighty-four sets of specimens were collected in five western states and on Vancouver Island. Cytological and morphological studies of the four western species were made from plants grown experimentally at the University of California. Bulbs of *Camassia scilloides* unfortunately failed to develop in this habitat.

In this paper, nomenclatorial status is not assigned to units subordinate to subspecies. The subspecies are intergrading populations within the species that combine the possession of a definite set of morphological characters with a definite geographical range. With the possible exception of *C. Cusickii* about which too little is known, the species of *Camassia* appear to be genetically distinct, at least in respect to the production of fertile hybrids. *Camassia Quamash* and *C. Leichtlinii,* as well as *C. Howellii* and *C. Leichtlinii* occur together in nature, and the absence of hybrids between them can be accepted as proof of their intersterility.

Phylogeny

Camassia was placed in the subfamily Scilloideae of the Liliaceae by Engler (1888) and by Krause (1930), and in the tribe Scilleae by Baker (1873). Hooker (1873) included it with the same associated genera in the tribe Hyacinthineae. Its closest affinities appear to be with three North American genera, *Chlorogalum, Schoenolirion,* and *Hesperocallis.* Earlier writers stressed a sup-

[1] This study was made at the University of California in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

posed relationship with *Scilla*, a genus widespread in Europe, western Asia, and Africa, and which has two species in South America but none in North America. *Camassia scilloides* of the eastern United States was first described as a species of *Scilla*, and, of the species *Camassia*, is most similar morphologically to members of this genus.

Camassia may be distinguished from *Chlorogalum* by its racemous rather than paniculate inflorescence and more numerous seeds. The number of seeds in *Chlorogalum* apparently never exceeds two per locule, while in *Camassia* as many as twelve seeds per locule are developed and two represents the minimum. *Schoenolirion*, similar to *Chlorogalum*, has small capsules with only one or two seeds per locule and has also smaller flowers and usually a more congested inflorescence than *Camassia*. *Hesperocallis* differs conspicuously from all three

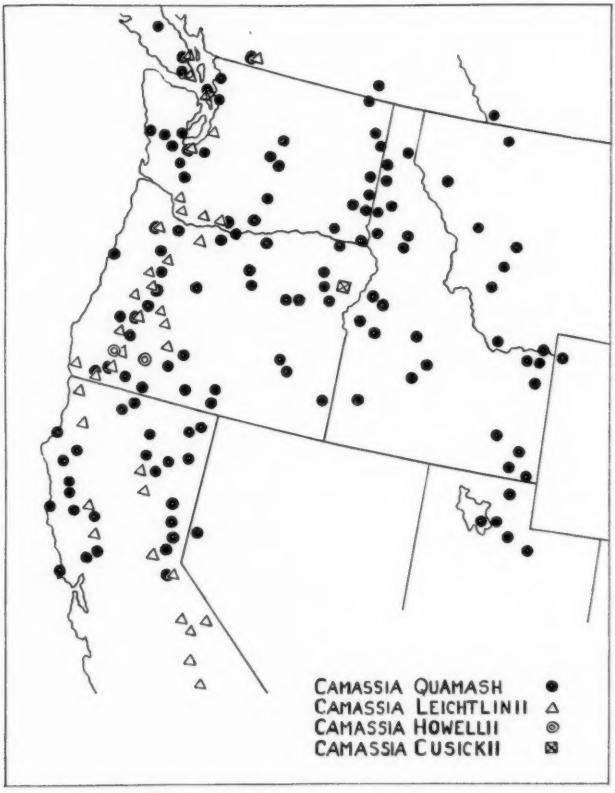

Fig. 1. Distribution of the western species of *Camassia*.

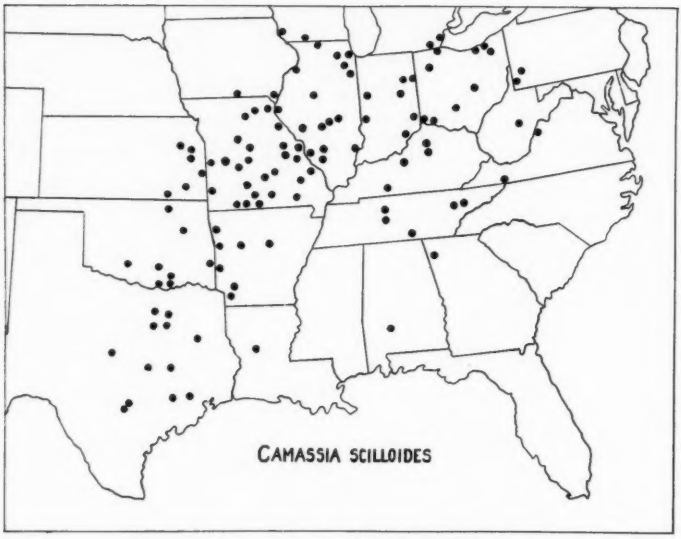

Fig. 2. Range of *Camassia scilloides* (Raf.) Cory.

of these genera in its tubular perianth and flattened seeds, but appears to be a desert adaptation from the same liliaceous stock.

The center of dispersal for *Camassia* was probably in southwestern Oregon where three species and five subspecies now occur. The mountains of this region constitute part of the oldest land mass in North America. *Camassia Howellii*, endemic to southwestern Oregon, appears to represent most nearly the primitive stock. This species has numerous characters in common with related genera, especially *Chlorogalum*. Significant in respect to its relationship with *Chlorogalum* are its numerous, regular flowers, usually 3-nerved perianth segments that become twisted together after a short period of anthesis, and its subglobose, few-seeded capsules. The occasional production of branched inflorescences in *Camassia Howellii* and *C. Leichtlinii* appears to have phylogenetic implications, inasmuch as this condition is characterstic in *Chlorogalum* and of frequent occurrence in *Schoenolirion*.

Assuming southwestern Oregon to be the place of origin for *Camassia* the following developments may be postulated. From a common prototype the *C. Howellii* and *C. Leichtlinii* genotypes came into existence. The former remained restricted to southwestern Oregon, perhaps becoming locally abundant, while the latter spread northward and southward along the coast, attaining perhaps an even greater range than it occupies today. At some point between the mouth of the Columbia River and Vancouver Island, *C. Leichtlinii* gave rise to *C.*

Quamash. Here the species are most similar at present, and frequently grow intermingled.

From its coastal origin the vigorous *C. Quamash* followed two lines of migration, southward along the western slopes of the Cascade Range or pre-Cascades, and eastward through the region of the Columbia River Valley. The southward extension was checked by the Siskiyou Mountains of southwestern Oregon and northern California, or the cross-ranges that preceded them. Here the species is represented by subsp. *intermedia* and subsp. *Walpolei*.

The eastward advance through the Cascades was followed by a fan-shaped spreading both northward and southward along the eastern slopes of this range and eastward to the Rocky Mountains. Here subspecies *typica, breviflora,* and *utahensis* became segregated. The dark-flowered *C. Quamash* subsp. *breviflora* progressed southward across eastern Oregon to the northern cross ranges and the Sierra Nevada of California. Subspecies *linearis* of the northern California coast ranges is closely related to subsp. *breviflora* and probably represents a westward extension of this small, dark-flowered *Camassia*. Both of these *C. Quamash* subspecies appear to have little in common with *C. Quamash* subsp. *Watpolei* of southwestern Oregon, although their geographical separation is a matter of only a few miles.

Camassia Cusickii, endemic to the Snake River country of northeastern Oregon, is probably a recent mutant of *C. Quamash* that has remained restricted to its place of origin. *Camassia scilloides,* now widespread in the eastern and southern states, appears to have migrated into its present range from some northerly center such as the Great Lakes Region. It seems most logical to assume a former connection with the western species in the region between the Rocky Mountains and the Great Lakes. *Camassia scilloides* would thus represent the final phase of a transcontinental migration from west to east.

Taxonomic History

The type collection of the genus was made by Lewis and Clark on their return trip from the Pacific Coast in the spring of 1806 at what is now Weippe Prairie, Clearwater County, Idaho. The party had become acquainted with "camas" the preceding fall when they obtained camas bulbs and dried salmon from the Nez Percé Indians in this region, after having descended the western slopes of the Rocky Mountains with a seriously depleted food supply. Pursh described these specimens as *Phalangium Quamash* (Fl. Amer. Sept. 1:226, 1814.) but erroneously gave the type locality as "upper Missouri River near the Rocky Mountains."

In 1813, before Pursh's Flora was published, Ker-Gawl described the *Camassia* of the eastern United States as *Scilla esculenta*. His species was based on plants grown in Fraser's Nursery in London, the original bulbs of which had been imported by Nuttall. There is some doubt as to where Nuttall obtained his plants, but they probably came from the vicinity of St. Louis,

Missouri. Ker-Gawl gave as synonyms of *Scilla esculenta; Phalangium esculentum* Nutt., a "nomen nudum" in Fraser's Catalogue; and *Phalangium Quamash* Pursh, unpublished at the time.

Rafinesque, in 1818, wrote in a review of Pursh's Flora: *"Phalangium quamash* or *Scilla esculenta* appears to be neither a *Scilla* nor a *Phalangium,* it has been called *Quamasia esculenta* by Raf. in Fl. Missurica." In the same year Rafinesque applied the name *Cyanotris scilloides* to the same species. Five years later Sprengel transferred it to *Anthericum,* treating both the eastern and western plants as one species, as had Rafinesque. The genus *Camassia* with the species *C. esculenta* (based on *Phalangium Quamash* Pursh) was delineated by Lindley in 1832. In "Flora Tellurina" (1836) Rafinesque added three generic synonyms, *Lemotris, Bulbedulis,* and *Lemotrys.* The first two were listed as "substitutes" for *Quamasia* (Fl. Tellur. 2(1):25) in case that name be considered "too barbarious." *Lemotrys* was used as the generic name for the eastern plants (Fl. Tellur. 3(73):50) when Rafinesque later concluded that they formed a genus separate from the western group. For the latter he retained the name *Quamasia.*

A long-standing controversy over the use of *Camassia* versus *Quamasia* was officially ended when the former was conserved at the International Botanical Congress in 1930. With the retention of *Camassia,* however, the specific epithet *esculenta* was invalidated in the genus. It is an earlier synonym of the name for the eastern species but was first used in the retained genus to designate one of the western species. *Camassia scilloides* (Raf.) Cory, based on *Cyanotris scilloides* Raf., is thus the proper name for the eastern species, and *Camassia Quamash* (Pursh) Greene for the western species.

Jeffrey in 1853 collected the bulbs of a white-flowered *Camassia (C. Leichtlinii)* in the Umpqua Valley of western Oregon. These were sent to England and there brought into cultivation. Baker, who first described this plant as a species of *Chlorogalum* and later as a variety of *Camassia esculenta* Lindl., stated (Gard. Chron. 2(1):689, 1874):

> This is a plant which has been widely spread in gardens both in England and on the Continent under the name of "White Camassia"—Our plant was received from Edinburg Botanical Garden, and I learned from M'Nab that it was collected by Mr. John Jeffrey in British Columbia in 1851. I do not find it from Jeffrey or any other collector in the Kew herbarium.

Baker apparently was misinformed both as to the time and place of collection of the original bulbs, as they were obtained by Jeffrey in 1853 (not 1851) in the Umpqua Valley. The probable source of this error was disclosed by Johnson's recent article on Jeffrey and the Oregon Expedition (1939). Johnson lists two white-flowered *Camassia collections, Jeffrey* no. *1007* from the Umpqua Valley, May 3, 1853, and *Jeffrey* no. *1283* from "the north banks of the Kootenay River," May 21, 1851. The Kootenay River flows northward from Boundary County, Idaho, to join the Columbia River in British Columbia. The white-flowered specimens of collection no. *1283* are probably albino plants of *C. Quamash,* the only *Camassia* of this region.

The taxonomic delimitation of species and subspecies in *Camassia* presents an interesting problem because inconsistencies in respect to taxonomic criteria and the range of species exist in all literature dealing with the genus. For example, peranth-nervation (whether the segments are 3- or 5-7-nerved) has been used by Coville, Jepson, Rydberg, and Tidestrom as a factor in separating *C. Leichtlinii* from *C. Quamash*. This distinction cuts directly across specific lines and has caused a confusion of the coastal segregates of the two species. Figure 3 gives a comparison of perianth nervation and other characters of taxonomic importance in the species and subspecies of *Camassia*. Difficulties in

Specific Criteria

	Perianth Segments										Fruiting Pedicels	
	Nervation			Connivence		Color		Regularity				
	All 3-nerved	Inner whorl 3-, outer 5-	5-, 7-, or 9-nerved	Connivent	Not Connivent	Pale	Dark	Regular	Zygomorphic	Spreading	Not Spreading
Camassia scilloides	94	5	1	1	99	30	70	100	0	95	5
C. Leichtlinii											
subsp. *typica*	1	15	84	100	0	100	0	100	0	100	0
subsp. *Suksdorfii*	1	20	79	100	0	0	100	100	0	99	1
C. Howellii	74	20	1	100	0	0	100	100	0	100	0
C. Quamash											
subsp. *typica*	80	15	5	0	100	80	20	1	99	1	99
subsp. *maxima*	0	25	75	0	100	1	99	1	99	40	60
subsp. *azurea*	0	25	75	0	100	99	1	5	95	95	5
subsp. *intermedia*	0	15	85	0	100	100	0	1	99	0	100
subsp. *Walpolei*	74	25	1	0	100	100	0	99	1	0	100
subsp. *utahensis*	89	10	1	95	5	85	15	1	99	1	99
subsp. *breviflora*	94	5	1	99	1	0	100	1	99	0	100
subsp. *linearis*	0	20	80	90	10	0	100	1	99	0	100
C. Cusickii	74	25	1	0	100	100	0	0	100	1	99

Fig. 3. Comparison, in percent, of the perianth and pedicel characters most frequently employed in distinguishing specific entities in *Camassia*. This chart clearly shows the necessity of employing combination of characters in species differentiation.

the taxonomy of the group have largely been due to insufficient knowledge of the *C. Quamash* species-complex. The characters used by previous writers do not separate *C. Quamash* from *C. Leichtlinii*. In fact the conditions supposed to characterize *C. Leichtlinii* occur also in certain populations of the other species, *C. Quamash* (see Figure 4). Because no presence and absence characters are available for separating the two species throughout their range, a combination of characters will be employed for that purpose.

Cytology

Cytological investigations were made by the writer in *Camassia Quamash*, *C. Leichtlinii*, *C. Howelii*, and *C. Cusickii*. The diploid chromosome comple-

ment in these species was found to be 15 pairs, the same as had been previously reported for *C. Cusickii* and *C. scilloides* (*C. esculenta* Robinson) (Tab. Biol. Period. 1(2):205, 1933). The chromosomes are not of uniform size, but form a grading series in which the smallest is about one-half of the largest. No comparison could be made of the *Camassia* karyotype with those of the related genera *Chlorogalum, Schoenolirion,* and *Hesperocallis* because cytological studies of these groups have not yet been made.

ACKNOWLEDGEMENTS

The author is indebted to Dr. Herbert L. Mason and Dr. Lincoln Constance for their assistance and helpful criticism during the course of this study, and to those persons who aided in obtaining plant materials, especially Mrs. G. A. Hardy of the Provincial Museum of British Columbia, Victoria, B.C., and Mr. William Hooker of the University of Wisconsin.

Grateful acknowledgement is made for the opportunity of examining material loaned by curators of the following herbaria: Provincial Museum of Natural History (BC), Victoria, B. C.; California Academy of Sciences (CA), San Francisco; National Museum of Canada (CAN), Ottawa; Field Museum of Natural History (F), Chicago; Gray Herbarium (G), Harvard University, Cambridge; Intermountain Herbarium (IH), Utah State Agricultural College, Logan; Missouri Botanical Garden (M), St. Louis; New York Botanical Garden (NY), New York; Academy of Natural Sciences (PA), Philadelphia; Rocky Mountain Herbarium (RM), University of Wyoming, Laramie; Dudley Herbarium (S), Stanford University; University of

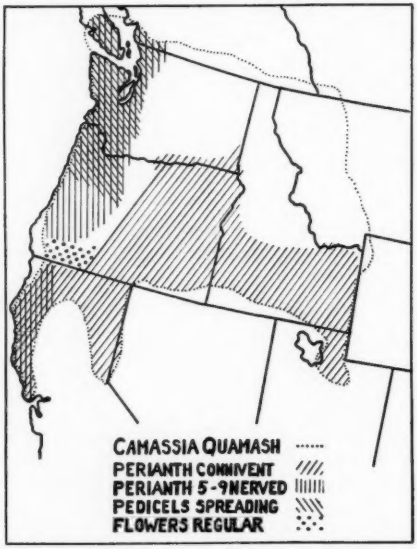

Fig. 4. Occurrence of conditions in the *Camassia Quamash* complex which frequently have been treated as exclusive characters of *C. Leichtlinii.*

California (UC), Berkeley; University of Idaho (UI), South Branch, Pocatello; University of Oregon (UO), Eugene; United States National Herbarium (US), Washington, D. C.; University of Washington (UW), Seattle; Vegetation Type Map Herbarium (VTM), California Forest Range Experiment Station, Berkeley; University of Wisconsin (WIS), Madison; State College of Washington (WS), Pullman.

Sets of specimens collected by the writer have been distributed to the above herbaria and are cited without reference to their placement. The types of the proposed subspecies have been deposited in the herbarium of the University of California.

Fig. 5. Fruiting racemes of *Camassia* species. 1 and 2, *C. Leichtlinii* subsp. *Suksdorfii*; 3, *C. Howellii*; 4, *C. scilloides*; 5, 6, 7, *C. Quamash* subsp. *linearis*; 8, *C. Quamash* subsp. *Walpolei*.

Taxonomy

CAMASSIA Lindley

Quamasia Rafinesque, Am. Mo. Mag. **2**:265. 1818.
Cyanotris Rafinesque, Am. Mo. Mag. **3**:356. 1818.
Camassia Lindley, Bot. Reg. t. 1486. 1932 (nomen conservandum).
Quamassia Rafinesque, Fl. Tellur. **2**:25. 1836.
Bulbedulis Rafinesque, Fl. Tellur. **2**:26. 1836.
Lemotris Rafinesque, Fl. Tellur. **2**:26. 1836.
Lemotrys Rafinesque, Fl. Tellur. **3**:50. 1836.
Sitcodium Salisbury, Gen. Pl. Fragm. 27. 1866.

Bulbous perennials with a simple, erect scape, a basal whorl of linear leaves, and a racemose inflorescence. Bulbs ovate, tunicated, black- or brown-coated, solitary or clustered. Leaves linear-lanceolate, entire, glabrous, keeled to about the middle from a thick midvein, bright green or glaucous on the adaxial surface, weakly erect or prostrate at maturity. Scape slender, terete, fibrous, unbranched, green or with a bluish luster on the upper portion. Inflorescence racemose, densely or loosely flowered; the pedicels 1 to 5 cm. long, the lower usually exceeding the upper, spreading or incurving-erect in fruit; the bracts

lanceolate-acuminate, 5- to 10-veined, green or bluish, becoming scarious at anthesis. Flowers large, regular to slightly zygomorphic; the perianth of 6 free narrow segments in two whorls of three, the inner frequently broader than the outer, the segments sessile or short-clawed, 3- to 9-veined, blue-violet, blue or white, spreading regularly or with five segments curving upward and the sixth downward; the androecium of six perfect stamens inserted on the receptacle at the base of the perianth segments; the anthers linear-oblong, yellow, blue-violet or brown, versatile on filiform filaments about three-fourths as long as the perianth segment. Ovary superior, 3-loculate, developing into a loculicidally dehiscent capsule; the style filiform, slightly longer than the stamens; the stigma 3-lobed or 3-parted. Capsule subglobose, ovate or oblong, few- to many-seeded; the carpels strongly cross-veined. Seeds obpyriform, the seed coats black or with a bluish luster, smooth or wrinkled at maturity.

KEY TO SPECIES OF CAMASSIA

I Perianth segments connivent over capsule after anthesis.
- A Flowers regular, usually only 1 to 3 blooming simultaneously, perianth segments soon deciduous, pedicels usually spreading-erect in fruit, the capsules not appressed to the axis of the raceme.
  - B Capsule ovate, 1.0 to 2.5 cm. long, dull green, locules 6- to 12-seeded; Vancouver Island to central California. ..... 1. *C. Leichtlinii*
  - BB Capsule subglobose, 0.5 to 1.0 cm. long, shiny green, locules 2- to 5-seeded; southwestern Oregon ..... 2. *C. Howellii*
- AA Flowers regular or zygomorphic with 5 perianth segments curving upward and the 6th downward, numerous flowers blooming simultaneously, withered perianth segments long persistent on fruiting raceme, pedicels incurving-erect in fruit, the capsules closely appressed to the axis of the raceme... 4. *C. Quamash*

II Perianth segments withering separately at base of the capsule after anthesis.
- C Capsule subglobose; eastern and southern United States. ..... 3. *C. scilloides*
- CC Capsule ovate or oblong; western North America.
  - D Bulbs large, clustered; leaves 2.0 to 4.0 cm. broad; northeastern Oregon, rare. ..... 5. *C. Cusickii*
  - DD Bulbs seldom clustered; leaves usually 1.0 to 1.5 cm. broad; a widespread polymorphic species. ..... 4. *C. Quamash*

1. CAMASSIA LEICHTLINII (Baker) Wats.

Chlorogalum Leichtlinii Baker, Gard. Chron. ser. 2. **1**:6899. 1874.
Camassia esculenta Lindl. var. *Leichtlinii* Baker, Curtis Bot. Mag. t. 6287. 1877.
Camassia Leichtlinii Watson, Proc. Am. Acad. **20**:376. 1885.
Camassia Suksdorfii Greenman, Bot. Gaz. **34**:307. 1902.
Quamasia Suksdorfii Piper, Contr. U. S. Nat. Herb. **11**:191. 1906.

Bulb 1.5 to 3.5 cm. in diameter; leaves 2 to 6 dm. long, 0.5 to 2.5 cm. broad; scape 2 to 13 dm. tall; raceme 4- to 60- or more-flowered; pedicels 1.5 to 5.0 cm. long, occasionally shorter, usually spreading-erect, never strongly incurving at base; bracts frequently shorter than pedicels; flowers regular, perianth blue-violet to cream-white, rarely pure white or shades of pink and light violet, perianth segments 2 to 4 cm. long, 0.4 to 1.0 cm. broad, twisting together over the capsule after a short period of anthesis and early deciduous from the fruiting raceme; anthers 0.4 to 0.7 cm. long before dehiscence; capsules

oblong or ovate, 1.0 to 3.0 cm. long, 0.6 to 1.2 cm. broad, readily deciduous from the pedicel at maturity, locules 6- to 12-seeded; seeds 2 to 4 mm. long, seed coat jet-black or with metallic-blue luster.

Type: The type description was made from living plants, grown from bulbs collected by John Jeffrey in the Umpqua Valley of Oregon, May 3, 1853. If a type specimen exists it is probably at Kew and hence unavailable at the present time. Under the circumstances it seems advisable to designate an authentic specimen for reference which represents "the plant" upon which the writer's account of the species is based.

Authentic specimen: OREGON. Douglas County: grain field 3 miles south of Days Creek, May 6, 1940, *Gould 1086* (UC).

Range: Southern Vancouver Island east to the Cascade Mountains, south to the northern coast ranges of California and the southern Sierra Nevada.

This species is regularly associated with *Camassia Quamash* from Vancouver Island to southern Oregon, but usually flowers two to three weeks later. It is best distinguished from *C. Quamash* in this region by the regular twisting together of its perianth segments after anthesis. In the northern coast ranges of California, *C. Leichtlinii* grows in mountain meadows, rarely below 2000

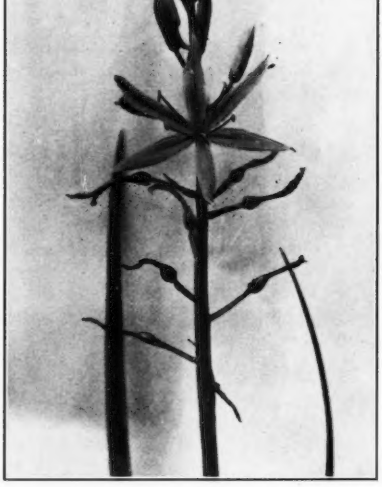

Fig. 6. Flowering raceme of *Camassia Leichtlinii* subsp. *Suksdorfii*. Note the regular-spreading perianth segments that become connivent and twisted together, the single flower in blossom, and the long, spreading pedicels.

feet altitude, while *C. Quamash* inhabits wet meadows from near sea level to about 2500 feet. Most collections of *C. Leichtlinii* from the Sierra Nevada have been made south of Lake Tahoe, where *C. Quamash* does not occur. The two have not been recorded together either in the California Coast Ranges or the Sierra Nevada. In California both the coastal and interior subspecies of *C. Quamash,* subsp, *linearis and* subsp. *breviflora* have perianth segments that become weakly or strongly connivent over the capsule in a manner similar to *C. Leichtlinii.* Both subspecies, however, have characteristically dense racemes, slightly zygomorphic flowers, short incurving-erect fruiting pedicels, and non-deciduous capsules, in contrast with the loose racemes, regular flowers, long, spreading or widely spaced pedicels, and readily deciduous capsules of *C. Leichtlinii.*

Two subspecies are recognized in *C. Leichtlinii,* based primarily upon perianth color, a characteristic considerably more stable in the species than in *C. Quamash.*

Perianth cream-white .....a. subsp. *typica*
Perianth blue-violet (with occasional albinos).....b. subsp. *Suksdorfii*

1a. **Camassia Leichtlinii** (Baker) Wats. subsp. **typica** nom. nov.

Chlorogalum Leichtlinii Baker, Gard. Chron. ser. 2. **1**:689. 1874.
Camassia esculenta Lindl. var. *Leichtlinii* Baker, Curtis Bot. Mag. t. 6287. 1877.
Camassia Leichtlinii Wats., l.c.
Quamasia Leichtlinii Coville, Proc. Biol. Soc. Wash. **11**:63. 1897.

Plants usually large, frequently over one meter tall; flowers with an extremely short period of anthesis, seldom more than 1 or 2 flowers of the raceme open simultaneously; perianth cream-white, the segments 5- to 9-veined, usually 2.5 to 3.5 cm. long.

Range: Endemic to Umpqua River Valley, Douglas County, Oregon, where it exists in pure stands separate from colonies of the blue-flowered subsp. *Suksdorfii.* The two sub-species are apparently perfectly interfertile. Five miles south of Roseburg a large field of *C. Leichtlinii* shows a complete series of flower-color variation from deep blue-violet to cream-white.

In subspecies *typica* the *C. Leichtlinii* peculiarity of a short period of anthesis is most fully expressed. Large colonies of this cream-white-flowered *Camassia* have been observed during daylight hours in which only a small percentage of the plants had open flowers, although fruits and buds were present on the same racemes.

Representative specimens: OREGON. Douglas County: Oakland, *Mrs. N. P. Gale* 55 (M); Sutherlin, *Gould* 1101, 1923 *L. E. Hunt* (WS,G); Deady, *Gould* 1099; Wilbur. *Thompson* 10154 (M); Winchester, *Gorman* 5625 (WS); Roseburg, *Gorman* 5713 (WS), *Cusick* 3883, 4090, 3824a (WS), *Gould* 1092; Looking glass, *Cusick* 3951 (WS); Dillard, 1924 *Abrams & Benson* (RM); Canyonville, *Eastwood & Howell* 1468 (CA), *Gould* 805, 1097; Days Creek, *Gould* 1086; Cow Creek Canyon, above West Fork, *Henderson* 12316 (UO); Glendale, 1915 *E. L. Smith* (CA).

1b. **Camassia Leichtlinii** (Baker) Wats. subsp. **Suksdorfii** (Greenm.) comb. nov.

Camassia Suksdorfii Greenman, Bot. Gaz. **34**:307. 1902.
Quamasia Suksdorfii Piper, Contr. U. S. Nat. Herb. **11**:191, 1906.

Perianth deep blue-violet to bright blue, or rarely of light shades of blue or violet, or occasionally albino; differing from subsp. *typica* in no other essential details.

Type: WASHINGTON. Klickitat County: Wet meadows of Falcon Valley, May and July 1881, *W. Suksdorf 251* (G).

Range: The entire range of the species.

The type of *C. Suksdorfii* was cited by Watson as part of *C. Leichtlinii*. Greenman failed to note this fact, and also believed that he detected specific differences in capsule and seed characters between the two color-phases. He observed that the seeds of the Suksdorf specimens had a bluish luster, an interesting character peculiar to *C. Leichtlinii*, but one which is not constant and apparently is not correlated with any other distinctive feature.

Camassia Leichtlinii subsp. *Suksdorfii*, similar to subsp. *typica*, is characteristically large and robust at low elevation, but in montane habitats, as in California, is usually slender, 2 to 5 dm. tall, and few-flowered. Specimens with unusually short pedicels have been collected in the northern coast ranges of California, but this condition appears to have no taxonomic significance.

Representative specimens: BRITISH COLUMBIA. Mainland: Chilowequack (Chilliwack), *J. M. Macoun* 54061 (G,M,NY), 1859 *P. V. LeRoy* (NY). Vancouver Island: Nanaimo, 1908 *J. Macoun* (CAN), 1907 *Rosendahl* (G,M,RM); Prospect Lake, 1880 *Engelman* (M); Victoria, Foul Bay, *Carter* 885 (BC,G), Beacon Hill, *Gould* 1147, Mt. Douglas, 1881 *J. M. Macoun* (BC), *Gould* 1158, Oak Bay District, *Gould* 1153, 1156. Bare Island: 1896 *Anderson* (BC,WS). Galiano Island: 1930 *W. A. Newcombe* (BC).

WASHINGTON. San Juan Co.: Freeman's Island, 1921 *E. L. Pickett* (WS); Stuart Island, *W. H. Lawrence* 91 (WS); Brown's Island, *S. M. & E. B. Zeller* 851 (M,NY). Island Co.: Whidby Island, *C. N. Jones* 9718 (UW), 1898 *O. A. Piper* (WS). King Co.: Seattle, 1892 *C. V. Piper* (WS,UW). Thurston Co.: Deschutes River, *Otis* 2060 (CA). Klickitat Co.: Bingen, *Suksdorf* 2663 (G,M,S,UC); Falcon Valley, *Suksdorf* 509 (G), 251 (F,G,M,UO). Skamania Co.: Chiquash Mountains, *Suksdorf* 2664 (G). Cowlitz Co.: Kalama, *Gould* 1186. Clark Co.: Heisson, 1931 *C. S. English Jr.* (UW); Pioneer, *Gould* 1111.

OREGON. Clackamas Co.: Summit Ranger Station, *E. L. Evinger* 210 (M); Canby, *Gould* 1189. Multnomah Co.: Base of Mount Hood, 1880 *Howell & Howell* 304 (G); Elk Rock, *Sheldon* 11934 (UO). Washington Co.: Forest Grove, 1894 *F. E. Lloyd* (NY), *Thompson* 563 (M,S). Marion Co.: Salem, *J. C. Nelson* 1348 (G); Newberg, *Gould* 1110; Jefferson, *Gould* 1191; Albany, *Applegate* 6800 (S). Polk Co.: Monmouth, *Gould* 1108. Linn Co.: Tangent, *Gould* 1192; Brownsville, *Gould* 1193; Halsey, 1195. Benton Co.: Corvallis, *Applegate* 9256 (S), 1919 E. *Luedinghaus* (M), *Kincaide* 51 (WS). Lane Co.: Eugene, *Applegate* 9262 (S), *Henderson* 162340 (UO); Goshen, *Gould* 1196; Oakridge, *Gould* 1197. Douglas Co.: Yoncalla, *Applegate* 6156 (S,UC); Oakland, 1881 *Howell* (UO); Roseburg, *Mrs. N. P. Gale* 1 (M,PA); Myrtle Creek, *Gould* 806, 1090, *Applegate* 9259 (S). Klamath Co.: Jack

Springs, *A. Evans* 211 (UO); Crater Lake National Park, *Applegate* 10700 (CA). Jackson Co.: Brownsboro, 1927 *J. H. Heckner* (PA). Josephine Co.: Sexton Mountain, *Applegate* 6154 (S,UC), *Gould* 802, 1056; Grants Pass, 1912 *Peck* (PA), 1889 *Howell*, *Gorman* 5668 (WS); Selma, *Henderson* 5785 (CA,M,RM,S,UO), *Gould* 810; Waldo, *Gould* 813, 1052. Curry Co.: Chetco River, *Henderson* 10133 (UO); Agnes, *Applegate* 7109 (S); Brookings, *Kildale* 8491 (S), *Abrams & Benson* 10706 (S); Gold Beach, *Hoyt* 45 (S).

CALIFORNIA. Del Norte Co.: French Hill, *Kildale* 9953 (S). Humboldt Co.: Junction of Willow Creek and Trinity River, *Tracy* 3388 (UC); Bald Mountain, *Tracy* 7179½, 4538 (UC); Sasseck Peak, *R. E. Goddard* 691 (UC). Plumas Co.: Bucks Lake, *Walsh* 1472 (UC). Butte Co.: Butte Meadows, *Heller* 11959 (CA,F,G, M,PA,RM,S,UC); Jonesville, *E. B. Copeland* 408 (CA,M,RM,S,UC,UO). Lake Co.: Mount Hull, *Hall* 9546a (UC); Cobb Mountain, *Eastwood & Howell* 5772 (CA), *Gould* 1029; Mt. Sanhedrin, *Heller* 5921 (G,M,PA,RM,S); Jonesville, *E. B. Copeland* 408 (CA,M,RM,S,UC,UO). Lake Co.: Mount Hull, *Hall* 9546a (UC); Cobb Mountain, *Eastwood & Howell* 5772 (CA), *Gould* 1029; Mt. Sanhedrin, *Heller* 5921 (G,M,PA,RM,S); Bartlett Springs, *Kildale* 4952 (S). Placer Co.: ....., 1892 *A. M. Carpenter* (NY,UC). El Dorado Co.: Rubicon Meadows, Lake Tahoe, *J. T. Howell* 1203 (CA). Mono Co.: Mono Lake, 1929 *M. E. Jones* (M). Tuolumne Co.: Yosemite National Park, Lake Eleanor, 1889 *Chestnut & Drew* (UC), Aspen Valley, *Mason* 317 (UC); Fahey Meadow, *Quick* 1473 (CA). Mariposa Co.: Yosemite National Park, Peregoy Meadows, 1872 *Gray* (G), *Schrieber* 2459 (UC, VTM), *Gould* 1270, Little Yosemite Valley, *Hall* 9047 (UC). Madera Co.: Ellis Meadow, *W. E. Bullard* 161 (VTM). Fresno Co.: Pineridge (Pine Ridge), *Hall & Chandler* 226 (M,PA,UC). Tulare Co.: Mt. Sillman, (Sequoia National Park), 1928 *Mrs. C. Derby* (CA), *Dudley* 1485 (S); Grant National Park, *Dudley* 1202 (S).

2. CAMASSIA HOWELLII Wats.

Camassia Howellii Watson, Proc. Am. Acad. **25**:135. 1889.
Quamasia Howellii Coville, Proc. Biol. Soc. Wash. **11**:65. 1897.

Bulb 1.5 to 3.0 cm. in diameter, bulb coats brown, long-persistent and rather fibrous; leaves narrow, 2.0 to 6.0 dm. long, 0.5 to 1.2 cm. broad; inflorescence racemous, rarely paniculate, 15-90-flowered; pedicels slender, 1.5-2.5 cm. long, closely placed on scape and strongly spreading; bracts inconspicuous, as long as or shorter than the scape; flowers regular; perianth deep blue-violet, segments 1.0 to 2.0 cm. long, 3.0 to 5.0 mm. broad, 3- to 5-veined, twisting together over capsule after a short period of anthesis and early deciduous from fruiting raceme; anthers yellow or violet; capsule subglobose, 0.5 to 1.0 cm. long, 0.5 to 0.8 cm. broad, shiny green, readily deciduous from pedicel at maturity, locules 2- to 5-seeded.

Type: OREGON. Josephine County: "Grants Pass," June, 1889, *T. Howell 1395* (G).

Range: Endemic to southwestern Oregon where it is known to occur in only two localities. Howell's type collection from "Grants Pass" probably was made on Sexton Mountain, 11 miles north of this city, where recent collections have been made.

Camassia Howellii grows with *C. Leichtlinii* in grassy meadows on Sexton Mountain, but comes into flower a week or two weeks later than that species. Although there is sufficient overlap in the flowering periods of the two to

insure abundant cross-pollination, no plants of hybrid nature have been observed in the locality.

Representative specimens: OREGON. Jackson County.: Trail, *J. T. Howell* 6816 (CA). Josephine Co.: Sexton Mountain, *Applegate* 9238 (S), *Gould* 803, 1078, *Peck* 14949 (S); "Grants Pass," *Howell* 1395 (G,M,PA,S,UC,UO,WS).

3. CAMASSIA SCILLOIDES (Raf.) Cory

Phalangium esculentum Nuttall, Fraser's Catalogue, 1813, (nomen nudum).
Scilla esculenta Ker-Gawl, Bot. Mag. t. 1574. 1813.
Quamasia esculenta Rafinesque, Amer. Month. Mag. **2**:265. 1818, (in part).
Cyanotris scilloides Rafinesque, Amer. Month. Mag. **3**:356. 1818.
Anthericum esculentum Sprengle, Linn. Syst. Veg. **2**:84. 1825, (in part).
Lemotrys hyacinthina Rafinesque, Fl. Tellur. **2**:26. 1836.
Scilla angusta Engelman & Gray, Boston Journ. Nat. Hist. **5**:237. 1845.
Camassia Fraseri var. *angusta* Torrey, Pac. R. R. Rept. **2**:176. 1855, (based on the then unpublished C. *Fraseri* Torr.).
Camassia Fraseri Torrey, Pac. R. R. Rept. **4**:147. 1857.
Sitcodium Esculentum Salisbury, Gen. Pl. Fragm. 27. 1866.
Quamasia hyacinthina Britton, ex. Britt. & Brown, Illust. Flora U. S. **1**:423. 1896.
Quamasia esculenta Coville, Proc. Biol. Soc. Wash. **11**:65. 1897.
Camassia angusta Blankinship, Rep. Mo. Bot. Gard. **18**:195. 1907.
Camassia esculenta Robinson, Rhodora **10**:31. 1908.
Quamasia angusta Piper, Proc. Biol. Soc. Wash. **29**:77. 1916.
Camassia hyacinthina Palmer & Steyermark, Ann. Mo. Bot. Gard. **22**:502. 1935.
Camassia scilloides Cory, Rhodora **38**:405. 1936.
Camassia hyacintina Palmer & Steyermark, Rhodora **40**:131. 1938.

Bulbs 1.0 to 3.0 cm. in diameter, bulb coats black or brown; leaves 2.0 to 6.0 dm. long, 0.5 to 2.0 cm. broad, usually narrow; scape slender, 2.5 to 7.0 dm. tall; raceme 5- to 100- (usually 15- to 35-) flowered; pedicels 0.5 to 3.0 dm. long, spreading-erect; bracts usually about as long as or shorter than the pedicels; flowers regular; perianth segments 0.7 to 1.5 cm. long, 2.0 to 5.0 mm. broad, 3- or 5-veined, blue-violet, blue, or white, varying in same colony, usually withering separately but occasionally connivent over the capsule; anthers bright yellow, 3 to 5 mm. long before dehiscence; capsules subglobose, 0.6 to 1.0 cm. long, 0.5 to 0.8 cm. broad, readily deciduous from pedicels at maturity; seeds 2 to 5 per locule.

Type: The type specimen is probably at Kew and thus unavailable at the present time. The original description was made from cultivated plants, the bulbs of which were collected by Nuttall, presumably at St. Louis, Missouri.

Range: Prairies and open woodlands, western Pennsylvania south to central Georgia, west to Texas, Oklahoma, eastern Kansas, and southern Michigan and Minnesota.

Camassia scilloides exhibits a wide range of habit differences, but with one possible exception apparently does not possess distinct geographical subspecies. The slender, small-flowered plants of Texas, Oklahoma, and Kansas have been treated as a separate species *(Scilla angusta, Camassia angusta)* and these, while certainly not specifically distinct from *Camassia scilloides*, perhaps comprise a distinct subspecies. Collections of apparently sterile specimens from numerous

localities in the above-mentioned region are of especial interest. These plants generally have small flowers whose perianth segments spread for a short time and then are connivent over the ovary. In most cases, fertilization apparently is not accomplished, and the flowers are deciduous without further development of the ovary. Representative specimens of this peculiar phase are:

OKLAHOMA. Osage Co.: Pawhuska, 1938, *Sr. M. Constance* (Mont. State). Le Flore Co.: Talihina, *E. J. Palmer* 39272 (G,M). Johnson Co.: Tishomingo, *H. W. Houghton* 3537 (G, NY). Murry Co.: Arbuckle Mountains, *Goodman* 2451 (M,NY); Platt National Park, *Merrill & Hagan* 441 (US), *Merrill* 262 (NY). Love Co.: Marietta, *G. W. Stevens* 89 (G).

TEXAS. Denton Co.: Denton, *McCart* 815 (NY). Smith Co.: Troupe, *Reverchon* 2774 (M,NY). Harris Co.: Houston, *Lindheimer* 61 (M, type of *Scilla angusta* Engelm. & Gray), *E. Hall* 650 (M).

It is apparent that much Texan *Camassia* is typical *C. scilloides*, and that different stages of intermediacy exists between this and the atypical plants. Further investigations are necessary to determine whether or not a distinct subspecies exists in the Oklahoma-Texas region.

Representative specimens: ONTARIO. White Island, opposite Anherstburg, 1902 *J. Macoun* (CAN).

PENNSYLVANIA. Allegheny Co.: Chartiers, 1871 *S. W. Knipe* (G,PA). Washington Co.: mouth of Mingo Creek, *J. Bright* 14476 (WS), 1932 *Bright* (WIS).

MICHIGAN. Wayne Co.: Rockwood, 1916 *B. F. Chandler* (US). Lenawee Co.: Adrian, 1890 *I. H. Wheeler* (G).

WISCONSIN. Green Co.: Dill, 1927 *J. J. Davis* (WS). Grant Co.: Basswood Grove, 1889 *Fitch* (S).

OHIO. Cuyahega Co.: Berea, 1895 *J. R. Watson* (WS), *W. E. Damon* 39 (RM). Portage Co.: Mantua, *R. J. Webb* 1426 (G). Lorain Co.: Brownhelm, 1888 *F. E. Leonard* (WIS), 1895 *F. D. Kelsey* (WIS). Lucas Co.: Toleda, 1899 *I. T. Pennypacker* (F). Putnam Co.: Columbus, 1840 *W. S. Sullivant* (G). Licking Co.: Granville, 1903 *D. D. Condit* (UC). Ross Co.: Chillicothe, *H. T. Safford* 832 (US), 1885 *Safford* (UC). Clermont Co.: Loveland, *J. F. James* 98 (S). Hamilton Co.: Cincinnati, *C. G. Lloyd* (1882) (PA,UO,US), 1883 *Lloyd* (G,M).

INDIANA. Adams Co.: Geneva, 1908 *Mrs. G. S. Porter* (G). Wells Co.: Harrison Twp., 1903 *Deam* (G,NY,US,WIS). Delaware Co.: Mincie, 1888 *Brady* (UC). Tippecanoe Co.: Lafayette, 1938 *W. Hooker* (CA,G,IH,M,S,UC), 1912 *L. O. Overholtz* (M). Franklin Co.: Meamora, *R. C. Friesner* 8700 (CA,RM,WIS,WS). Vigo Co.: Terre Haute, 1890 *C. Rutter* (US). Jefferson Co.: Madison, *C. R. Barnes* 58 (S); Hanover, 1874 J. M. Coulter (PA,US).

ILLINOIS. Winnebage Co.: ....., 1858 *Bebb* (G,M,PA,US); Fountaindale, 1848 *Bebb* (M,NY,US). Stevenson Co.: Freeport, 1898 *C. F. Johnson* (UO). Cook. Co.: Chicago, *W. S. Moffatt* 1699 (RM), 1877 *H. F. Garger* (NY), *Greenman* 2585 (M); Maywood, 1897 *Chase* (G,RM). DuPage Co.: Lisle, 1919 *I. O. Martinek* (US), 1900 *Umbach* (WIS); Hinsdale. 1871 *H. H. Babcock* (G); Warrenville, 1896 *Umbach* (G,PA,RM,US,WIS). Kane Co.: Aurora, *J. E. Boyce* 2938 (G). Will Co.: Joliet, 1863 *W. Booth* (G). Kankakee Co.: *C. C. Crampton* 6 (US). Rock Island Co.: Port Byron. 1897 *Harper & Harper* (PA,US,WIS). Peoria Co.: Peoria, 1881 *Dr. Stewart* (PA). Champaign Co.: Glover, *F. C. Gates* 1549.7 (CA,G,RM); Stanton. *A. S. Pease* 17748 (G). Piatt Co.: White Heath, 1925 *E. C. Driver* (RM).

Macon Co.: Decatur, *H. A. Gleason* (G). Hancock Co.: Augusta, 1842 *S. B. Mead* (M). Morgan Co.: ....., 1872 *J. M. Milligen* (G,US). Wabash Co.: Mt. Carmel, 1888 *Trelease & Schneck* (M). Clinton Co.: Querus Lake, 1917 *O. S. Ledwan* (M). Washington Co.: Venedy, *Anderson* & *Woodson* 6 (M). St. Clair Co.: ....., 1877 *Eggert* (CAN,G,M,RM,S,UC,US).

IOWA. Scott Co.: Davenport, ..., *Parry* (M,NY). Lee Co.: ....., 1874 *T. D. Kellogg* (NY). Decatur Co.: ..... *Fitzpatrick* & *Fitzpatrick* 49 (G,M,NY,RM).

VIRGINIA. Bath Co.: Warm Springs, 1924 L. Sowden (PA). Smyth Co.: Marion, 1892 *Britton & Britton* (NY,PA); Mollies Knob, 1892 *Small* (F,G,M).

WEST VIRGINIA. Webster Co.: Wheeling, 1877 *H. N. Mertz* (NY).

KENTUCKY. Scott Co.: Stamping Ground, *J. W. Singer* 55 (US). Fayette Co.: Lexington, 1835 *R. Peter* (PA), ..., *Danberry* (UC). Nelson Co.: Nazareth, *Agnes* 1254 (CA,NY,S,UC). Hardin Co.: Howard, *Pennell* 11718 (PA). Warren Co.: Barren River, 1890 *S. F. Price* (M).

MISSOURI. Clark Co.: Wyaconda, 1918 *E. Blaetner* (G). Adair Co.: Kirksville, 1886 *C. S. Sheldon* (UC). Marion Co.: Hannibal, *Davis* 3890 (NY). Saline Co.: ....., *Bush* 14726 (M,US), 1897 *Mackenzie* (RM). St. Louis Co.: Allentown, *Payson* 1644 (RM), 1898 *Letterman* (M,UC); Meremec Highlands, *Bartrum* 1466 (PA,UO), *M. Craig* 3014 (CA,UC); Osage Hills, *Steyermark* 22498 (F); Kirkwood, *L. Hubricht* B1401 (M); Valley Park, *E. L. Evinger* 701 (G,M). Warren Co.: Truesdale, *Davis* 7362 (M). Cooper Co.: *Bush* 14751 (M). Johnson Co.: Warrensburg, *Sheldon* 8089 (M,NY,UW). Cass Co.: 1871 *G. C. Broadhead* (S). Jefferson Co.: DeSoto, 1896 *Eggert* (M); Sulphur Springs, 1927 *M. Mathias* (M); Selma, 1936 *M. E. Diemer* (WIS). Franklin Co.: Gray Summit, *Greenman* 4537 (M). Morgan Co.: ....., *Bush* 13598 (M). Benton Co.: Cole Camp, *Palmer* 30046 (M,PA). St. Genevieve Co.: Bloomsdale, *J. H. Kellogg* 1656 (M). Phelps Co.: Jerome. 1914 *Kellogg* (M). Iron Co.: Arcadia, *Payson* 2439 (RM), *Greenman* 4769 (M); Buzzard Mountain, 1897 *C. Russell* (M). Lacede Co.: Lebanon, *Pennell* 11649 (PA). Green Co.: Springfield, 1887 *Blankinship* (US); Willard, 1887 *Blankinship* (M). Jasper Co.: Webb City, *E. J. Palmer* 291 (M); Carthage, *Palmer* 25278 (M). *C. Mann* 1506 (M). Douglas Co.: Richville, *Steyermark* 18564 (M). Christian Co.: Chadwick, *Bush* 4445 (M). Taney Co.: Walnut Shade, *Bush* 15344 (M). Stone Co.: Cape Fair, *Steyermark* 10374 (M); Reeds Spring, *Bush* 15364 (M). Barry Co.: Seligman, *Palmer* 29797 (M).

KANSAS. Douglas Co.: Lawrence, 1892 *M. A. Carleton* (N,NY,US). Shawnee Co.: Topeka, ..., *H. H. Wright* (WIS). Franklin Co.: Ottawa 1907 *A. G. Parker* (WIS). Princeton, 1902 *G. R. Meeker* (M). Linn Co.: Pleasanton, 1929 *E. Anderson* (M). Wilson Co.: ....., *W. H. Haller* 833 (US,G,NY,RM); ....., *Palmer* 21381 (NY). Cowley Co.: ....., *M. White* 67 (M).

TENNESSEE. Jefferson Co.: Dandridge, 1842 *Rugel* (NY). Knox Co.: Knoxville, *A. Ruth* 778 (M). Davidson Co.: Nashville, 1883 *A. Gattinger* (S), *E. B. Harger* 7812 (G). Williamson Co.: Franklin, 1898 *Eggert* (NY). Franklin Co.: Sequanee, *H. K. Svenson* 7481 (G,PA,UC); Cowen, 1898 *Eggert* (M).

ARKANSAS. Washington Co.: Fayetteville, *Fassett* 19699 (WIS), *F. L. Harvey* 71 (M); Savoy, *Fassett* 17318 (WIS,WS). Faulkner Co.: Conway, *Haas & Haas* 169 (US,WIS,WS). Logan Co.: Magazine Mountain, *Palmer* 24848 (M). Sebastian Co.: Midway, *Palmer* 33289 (NY); Hartford Station, 1903 *H. A. Pilsbury* (PA). Polk Co.: Mena, *H. C. Benke* 5487 (G, US). Hempstead Co.: Fulton, *Bush* 1334 (M). Miller Co.: Texarkana, *Bush* 2242 (M).

OKLAHOMA. Osage Co.: Pawhuska, 1938 *Sr. M. Constance* (Mont. State). Tulsa Co.: Tulsa, S. D. *McKelvey* 2517 (G). LeFlore Co.: Talihina, *Palmer* 39372 (G,M); Pine Valley, *G. J. Goodman* 2499 (M). Murray Co.: Price's Falls, *R. Stratton* 9

(M); Platt National Park, *Merrill & Hogan* 441 (NY,US), *Merrill* 262 (NY). Comanche Co.: Ft. Sill, *Mrs. J. Clements* 11537 (CA, M, RM). Johnson Co.: Tishomingo, *H. W. Houghton* 3537 (G,NY). Marshall Co.: Madill, *W. Watson* 62 (CA). Love Co.: Marietta, *G. W. Stevens* 89 (G).

GEORGIA. Floyd Co.: Rome, ... (M).

ALABAMA. Wilcox Co.: 1840 *L. B. Buckley* (NY,UC).

LOUISIANA. Natchitoches Co.: Natchitoches, 1839 *J. Hale* (US).

TEXAS. Collin Co.: ....., *McCart* 1571 (NY). Dallas Co.: Dallas, *Curtis* 2938 (M,PA), *Reverchon* 4028 (G,M,NY). Tarrant Co.: Fort Worth, *Ruth* 234 (G, NY, PA,US,WIS). Smith Co.: Troupe, *Reverchon* 2774 (M,NY). Brown Co.: Brownwood, *Palmer* 11433 (G,M,NY,US). Robertson Co.: Franklin, *Cory* 21708 (G). Bell Co.: Temple, *L. Pace* 202 (M). Harris Co.: Houston, *Lindheimer* 61 (M. Type of *C. angusta* Engelm. & Gray), *E. Hall* 650 (M). Comal Co.: New Braunfels, *Lindheimer* 541 (M).

4. CAMASSIA QUAMASH (Pursh) Greene

Phalangium Quamash Pursh, Fl. Am. Sept. **1**:226. 1814.
Quamasia esculenta Rafinesque, Amer. Month. Mag. **2**:265. 1818, (in part).
Anthericum esculentum Sprengle, Linn. Syst. Veg. **2**:84. 1825, (in part).
Camassia esculenta Lindley, Bot. Reg. *t.*1486. 1832.
Scilla Kamas Nuttall, Journ. Acad. Nat. Sc. Phila. **7**:55. 1834.
Camassia Quamash Greene, Man. Bot. Bay Region 313. 1894.
Quamasia Quamash Coville, Prov. Biol. Soc. Wash. **11**:64. 1897.
Quamasia azurea Heller, Bull. Torr. Bot. Club **26**:547. 1899.
Camassia Leichtlinii var. *Watsonii* M. E. Jones, Contr. West. Bot. **14**:29. 1912.
Quamasia Walpolei Piper, Proc. Biol. Soc. Wash. **29**:81. 1916.
Camassia Walpolei Macbride, Contr. Gray Herb. n.s. **56**:14. 1918.
Camassia Teapeae St. John, Flora S. E. Wash. & Adj. Ida. 88. 1937.

Bulbs 1.0 to 3.0 cm. in diameter, bulb coats black or brown; leaves 0.5 to 2.0 cm. broad, 1.5 to 6.0 dm. long; scape 2.0 to 8.0 dm. tall; raceme 4- to 35-flowered; pedicels usually 0.5 to 1.5 cm. long, occasionally to 3.0 cm. in coastal subspecies; bracts usually as long as or longer than the pedicels, frequently broad and conspicuous; flowers zygomorphic or regular, usually zygomorphic and regular flowers occurring on the same raceme; perianth blue-violet, blue or white, perianth segments 1.2 to 3.5 cm. long 0.2 to 0.8 cm. broad, sessile or short clawed, acute or obtuse at apex, 3- to 9-veined, withering separately or connivent over capsule after anthesis, persistent on fruiting raceme; anthers bright yellow to dark blue-violet; capsules usually ovate, 0.8 to 2.5 cm. long, locules 5- to 10-seeded; seeds 2.0 to 4.0 mm. long, seed coats black.

Type: IDAHO. Clearwater County: "near the foot of the Rocky mountain on the Quamash flats" (Weippe Prairie), June 23, 1806, *M. Lewis* (PA).

Range: Vancouver Island to the northern coast ranges of California and the northern Sierra Nevada, east to western Montana and northern Utah. A few collections have been made in southern Alberta and on the British Columbian mainland.

KEY TO SUBSPECIES OF CAMASSIA QUAMASH

A Perianth segments withering separately, with no tendency to be connivent over the capsule.

B Fruiting pedicels spreading, not strongly incurving-erect, capsules held away from the axis of the raceme.

c Perianth light blue-violet; bulbs uniformly small, shallowly buried in light, well-drained prairie soils; alluvial plains of southwestern Washington..... .....4c. subsp. *azurea*

cc Perianth bright to deep blue-violet; bulbs small or large; wet meadows, fields, and rocky coastal slopes, Vancouver Island to northwestern Oregon .....4b. subsp. *maxima*

BB Fruiting pedicels incurving-erect, capsules usually closely appressed to the axis of the raceme.

D Flowers regular, the perianth segments 1.2 to 2.0 cm. long; pedicels usually 0.5 to 1.0 cm. long; southwestern Oregon .....4e. subsp. *Walpolei*

DD Flowers slightly zygomorphic or regular, the perianth segments usually more than 2.0 cm. long; pedicels 1.0 to 2.5 cm. long.

E Perianth segments deep blue-violet.

F Perianth segments 0.5 to 1.0 cm. broad, 5- to 9- veined, the outer whorl occasionally 3-veined; western Washington and northwestern Oregon .....4b. subsp. *maxima*

FF Perianth segments usually 0.3 to 0.5 cm. broad and 3- or 5-veined; interior Washington and east to Rocky Mountains .....4a. subsp. *typica*

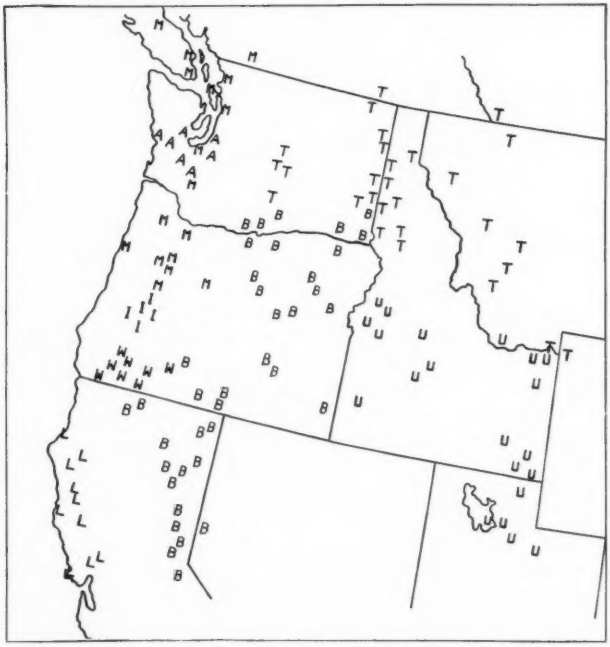

Fig. 7. Map of the distribution of the subspecies of *Camassia Quamash* (Pursh) Greene.

CAMMASSIA QUAMASH

Subsp. *Typica* T Subsp. *Azurea* A Subsp. *Walpolei* W Subsp. *Breviflora* B
Subsp. *Maxima* M Subsp. *Intermedia* I Subsp. *Linearis* L Subsp. *Utahensis* U

EE Perianth segments pale blue or blue-violet.
G Perianth segments usually 3-veined, or the inner whorl 5-veined; anthers dull yellow to blue-violet; interior Washington and east to Rocky Mountains ..... 4a. subsp. *typica*

GG Perianth segments usually 5- or 7-veined, the outer whorl occasionally 3-veined; anthers bright yellow; southwestern Oregon..... 4d. subsp. *intermedia*

AA Perianth segments connivent over the capsule, usually being forced apart again by growth of the capsule.
H Perianth segments 5- to 9-veined, or the outer whorl occasionally 3-veined; leaves narrow, uniformly green above and below; northern California coast ranges ..... 4f. subsp. *linearis*

IIII Perianth segments usually 3-veined, or the inner whorl 5- and the outer 3-veined; leaves usually broad, glaucous on adaxial surface.
I Perianth segments 1.5 to 2.0 cm. long, bright blue to deep blue-violet; anthers bright yellow; Sierra Nevada north to Washington..... 4g. subsp. *breviflora*

II Perianth segments 2.0 to 3.0 cm. long, pale to deep blue-violet; anthers often tinged with blue or brown; Utah and southern Idaho..... 4h. subsp. *utahensis*

4a. Camassia Quamash (Pursh) Greene subsp. typica, nom. nov.

Phalangium Quamash Pursh, Fl. Am. Sept. **1**:226. 1814.
Quamasia esculenta Rafinesque, Amer. Month. Mag. **2**:265. 1818, (in part).
Anthericum esculentum Sprengle, Linn. Syst. Veg. **2**:84. 1825, (in part).
Camassia esculenta Lindley, Bot. Reg. *t.*1486. 1832.
Scilla Kamas Nuttall, Journ. Acad. Nat. Sc. Phila. **7**:55. 1834.
Camassia Quamash Greene, Man. Bot. Bay Region 313. 1894.
Quamasia Quamash Coville, Proc. Biol. Soc. Wash. **11**:64. 1897.
Camassia Leichtlinii var. Watsonii Jones, Contr. West. Bot. **14**:29. 1912.
Camassia Teapeae St. John, Flora S. E. Wash. & Adj. Ida. 88. 1937.

Leaves 2.0 to 5.0 dm. long, 0.6 to 2.0 cm. broad, glaucous on adaxial surface; scape 2.5 to 7.0 dm. tall; pedicels 1.0 to 2.0 cm. long, incurving-erect in fruit; bracts as long as or longer than pedicels, generally narrow and inconspicuous; flowers usually zygomorphic; perianth segments 1.5 to 3.0 cm. long, typically 0.5 cm. or less broad; deep blue-violet to pale blue or white, 3-, 5-, or rarely 7-veined, withering separately at base of capsule; anthers usually dark (blue-violet or brown) even when perianth segments are light colored.

Range: Southern Alberta and southeastern British Columbia, western Montana and Yellowstone National Park, northern Idaho, to southern Washington and northern Oregon.

Subspecies *typica* is an aggregate of forms that differ considerably from one another but do not seem to be sufficiently distinct to be recognized as subspecies. A small-flowered form of central Washington (Chelan, Kittitas, and Yakima counties) is similar in habit to *C. Quamash* subsp. *Walpolei* of southern Oregon. It typically has short, sub-equal pedicels, small flowers whose perianth segments are strongly reflexed in anthesis, and small capsules. This phase of *C. Quamash* grades into subsp. *breviflora* in Yakima County. Subspecies *typica* predominantly has light colored flowers, but colonies of dark-flowered plants are not uncommon throughout its range.

St. John gave specific rank to the slender, pale-flowered plants of northern Idaho and adjacent Washington, as *C. Teapeae*. This segregate is based mainly on the rather trivial characters of bulb coat color, and the clawing of the perianth segments, both of which are of slight taxonomic significance. The color of the bulb coats appears to be largely dependent upon edaphic factors, and clawed perianth segments occur frequently in most subspecies of *C. Quamash*.

Representative specimens: ALBERTA. Crowsnest Forest Reserve, 1920 *W. D. Cram* (CAN); between Waterton and Pincher Creek, 1925 *M. O. Malte & W. R. Watson* (CAN,G).

BRITISH COLUMBIA. Deer Park, *J. M. Macoun* 27461 (CAN,G); Trail, 1902 *Macoun* (CAN,NY).

MONTANA. Glacier Co.: Glacier Park (Midvale), *Umbach* 61 (NY,R,S), *Standley* 15150 (US). Sanders Co.: Thompson Falls, *Hitchcock* 2247 (CA,M,PA,RM,S, UO,W), *Hughes* 1058 (CA,F,M,UC,UO), *Kirkwood* 1058 (F,NY,RM,WIS). Lewis and Clark Co.: Helena, 1893 *E. Startz* (M). Missoula Co.: Sunset, *E. W. Scheuber* 303 (NY), *Gould* 493b; *Evaro*, 1909 *M. E. Jones* (G), 1902 *Blankinship* (&C). Silver Bow Co.: *Butte, Mrs. P. H. Moore* 1093 (M). Beaverhead Co.: 13 miles east of Jackson, 1926 *Blankinship* (RM); ....., *F. Tweedy* 100 (NY).

IDAHO. Bonner Co.: Hope, *M. B. Dunkle* 387 (RM). Kootenai Co.: Worley, *St. John, Gessel, Jones, Ridout, Woods* 4243 (ES); Spirit Lake, *St. John* 9372 (M,WS). Benewah Co.: Forks of St. Maries River, *Lieberg* 1178 (G,N,MY,RM, S,UC,UO); Benewah, *G. N. Jones* 307 (WS). Latah Co.: Moscow, *Constance & Rollins* 1069 (G,IH,M,NY,RM,S,UC,NW,WS), *St. John* 10558 (WS), *Abrams* 633 (UC). Clearwater Co.: Weippe (type locality, *Constance, Henrick, & Peters* 1890 (UC,US,WS), *Gould* 494a, *Beetle & Constance* 2626 (UC). Idaho Co.: Lewis & Clark Camp opposite Kamiah, *Applegate* 6728 (S). Nez Perce Co.: Lake Waha, *Heller* 3159 (M,NY,S); Lapwai Agency, *Sandberg, McDougal, & Heller* 132 (F,G,M,NY,S). Freemont Co.: Henrys Lake, *Nelson & Nelson* 5489 (M,RM).

WASHINGTON. Pend Oreill Co.: Usk, *St. John* 7043 (WS), *C. H. Spiegelberg* 94 (WS); Newport, *Spiegelberg* 93 (WS); Cusick, *St. John, Pickett, Davidson, Warren* 7044 (WS, type of *C. Teapeae*); Post Falls, *St. John, Gessel, Jones* 4290 (WS). Stevens Co.: Columbia River Valley, 1911 *M. B. Gabby* (WS); between Kettle and Columbia rivers near International Boundary, *J. M. Macoun* 70208 (NY). Spokane Co.: Spokane, *Leiberg* 58 (CA,UO,WS), *Nelson & Nelson* 627 (M,RM), *R. C. Stillinger* 10 (IH); Bonne Lake, *St. John, Pickett, & Warren* 3170 (WS); Hangman (Houzman) Creek, *Leiberg & Sandberg* 57 (CAN,F,G,M,NY,PA,UC,US); Chattaroy, 1927 *K. C. Jones* (WS); Fort Wright, 1913 *G. W. Turreson* (RM). Chelan Co.: Leavenworth, *Otis* 675 (CA), *St. John, Eggleston, Beals, & Warren* 9482 (WS); Cashmere, *Benson* 1288 (UW,WS); Chiwaukum, *St. John, Eggleston, Beals, & Warren* 8441 (WS). Whitman Co.: Pullman, *C. S. Parker* 443 (F,NY,S,WS), *C. V. Piper* 1677 (F,NY,RM,UW,WS); Colfax, *Hitchcock & Samuel* 2601 (CA,PA,RM,UO); Rock Lake, *G. Weitman* 103 (WS); Palouse Falls, *St. John & Pickett* 6158 (WS). Kittitas Co.: Teanaway Valley, *Thompson* 6340 (G,M,PA), *Quick* 1033 (UC); Wenatchee Mountains, *Cotton* 1194 (RM,WS); Colockum Pass, *H. W. Smith* 1203 (UW,WS); Ellensburg, 1921 *W. E. Davis* (WS). Yakima Co.: *H. T. Heidenreich* 77 (UW,WS). Klickitat Co.: Falcon Valley, *Suksdorf* 252 (PA,S); west Klickitat County, *Suksdorf* 63, 508 (G).

OREGON. Wasco Co.: between Mosier and The Dalles, *Beetle & Constance* 2624 (UC); The Dalles, *G. N. Jones* 4513 (G); Rowena, *Thompson* 10381 (M).

WYOMING. Yellowstone National Park; west entrance, *Applegate* 6368 (S,UC, WS); Yellowstone Lake, *Blankinship* 477a (F,PA), 1900 *W. W. Jones* (UC).

4b. **Camassia Quamash** (Pursh) Greene subsp. **maxima,** subsp. nov.

Folia semper utrinque viridia; pedicelli 1-3 cm. longi, inflexo-erecti vel directi et patentes; perianthii segmenta 2.0-3.5 cm. longa, 0.5-1.0 cm. lata, caeruleo-violacea, 5-9-nervia, exteriora interdum 3-nervia, post anthesin separatim marcescentia.

Bulbs black or brown coated; leaves 2.0 to 6.0 cm. long, 0.6 to 1.5 cm. broad, often slightly glaucous on adaxial surface; scape 2.5 to 8.0 dm. tall; pedicels 1.0 to 3.0 cm. long, spreading or incurving-erect in fruit; bracts broad, as long as or longer than the pedicels; flowers zygomorphic or regular; perianth segments bright blue to deep blue-violet, 2.0 to 3.5 cm. long, 0.5 to 1.0 cm. broad, usually 5- to 9-veined but at times outer whorl 3-veined, withering separately at base of capsule; anthers dull yellow to violet or brown.

Type: OREGON. Lane County: Wet meadow 5.4 miles north of Eugene, May 7, 1940, *Gould 1105* (UC).

Range: Southern Vancouver Island and the southwestern British Columbian mainland to western Washington and northwestern Oregon; in fields, meadowlands, and on rocky bluffs near the coast, at from near sea-level to 2000 feet altitude.

Subspecies *maxima* intergrades with the prairie ecotype *C. Quamash* subsp. *azurea* in western Washington, and with subsp. *intermedia* in central-western Oregon. The Cascade Mountains of central Washington form a barrier between it and *C. Quamash* subsp. *typica,* although in the Columbia Valley there are forms intermediate between subspecies *maxima, typica,* and the stubby-flowered *breviflora.*

The common occurrence of *C. Quamash* with *C. Leichtlinii* in western Washington and Oregon has not been generally recognized. Although these two species are about equally abundant in this region, Piper stated (1916): "In the area west of the mountains named (Cascade Mountains and the Sierra Nevada) *Q. quamash (C. Quamash)* is a rare plant." *Camassia Quamash* generally matures two to three weeks ahead of *C. Leichtlinii* in the same locality, and often is completely in fruit before the latter is well in flower. The two are readily distinguished in Oregon, Washington, and British Columbia by the characteristic twisting together of the perianth segments and the short period of anthesis of the flowers of *C. Leichtlinii.*

Representative specimens. BRITISH COLUMBIA. Mainland: Chilliwack, 1901 *J. Macoun* (CAN). Vancouver Island: Nanaimo, *Rosendahl* 1895 (G); Alberni, *W. R. Carter* 191 (G); Port Alberni, *Henry* 1212 (G.RM); Victoria, 1887 *J. Macoun* (CAN,G,NY), *Gould* 1148, 1150; Esquimalt, 1918 *J. R. Anderson* (WS); Thetis Lake, 1905 *Anderson* (WS); Colewood, *McCabe* 5694 (UC); Sooke, *McCabe* 5671 (UC), *Gould* 1161.

WASHINGTON. Skagit Co.: Deception Pass State Park, *H. W. Smith* 600 (UW); Anacortes, *C. L. Hitchcock* 3444 (CA,IH,RM,S,UC,US,WS) Fidalgo Island, *Hitchcock & Martin* 4666 (NY), *J. W. Thompson* 6081 (G,M), *Mason* 5307 (UC); mouth of Skagit River, 1927 *L. Roush.* Snohomish Co.: Marysville, 1928 *J. M. Grant* (RM).

Island Co.: Whidby Island, *H. W. Smith* 503 (WS). Thurston Co.: Tenino, *Otis* 2062 (S). Lewis Co.: Marys Corners, *Gould* 1118; Forest, *Gould* 1170.

OREGON. Washington Co.: Forest Grove, 1893 *F. E. Lloyd* (NY). Clackamas Co.: Oswego, 1893 *Howell* (UC,UO); Summit Ranger Station, *E. L. Evinger* 209 (M). Marion Co.: Silverton, *Gould* 1190; House Mountain, *Peck* 14632 (M); Salem, *Thompson* 4125 (PA,S), *J. C. Nelson* 1063 (G). Polk Co.: Rickreall, *Gould* 1109; *Independence*, 1894 *W. J. Spillman* (WS). Lincoln Co.: Devils Lake, *Gorman* 7563 (UO); Otter Crest State Park, *Beetle & Constance* 2627 (UC). Linn Co.: Halsey, *Gould* 1194. Benton Co.: Corvallis, *Epling & Shorett* 5027 (M), *Applegate* 9255 (S), 1892 *A. I. Mulford* (NY,M). Lane Co.: Mt. Scott, *Sheldon* 12995 (UO); Eugene, *Gould* 1105.

4c. **Camassia Quamash** (Pursh) Greene subsp. **azurea** (Heller), comb. nov.

Quamasia azurea Heller, Bull. Torr. Bot. Club **26**:547, 1899.

Bulbs brown-coated; leaves 1.5 to 4.0 dm. long, 0.4 to 1.3 cm. broad; scape 2.5 to 6.0 dm. tall; pedicels 1.0 to 2.5 cm. long, usually spreading in fruit so that the capsules are held away from the scape; flowers slightly zygomorphic or regular; perianth segments light blue-violet, 1.5 to 3.0 mm. broad, 5- to 9-veined or outer whorl 3-veined, withering separately at base of capsule.

Type: WASHINGTON. Grays Harbor County: "near Montesano," June 13, 1898, *A. A.* and *E. G. Heller 3933* (PA).

Range: Alluvial plains of western Washington, in moss- or grass-dominated prairies.

Originally described as *Quamasia azurea* by Heller, this *C. Quamash* ecotype was put in synonymy with *C. Leichtlinii* by Piper (1916). In describing his species, Heller stated,

> Our No. 3933, collected near Montesano, Chehalis County (now Grays Harbor County), Washington, June 13, 1898, on grassy slopes. The type specimen is in my private herbarium. This species differs considerably in habit from *Quamasia Quamash*, which is usually found in places where there is considerable moisture in the early spring, while later in the season the ground becomes dry and baked. The flowers of *Q. Quamash* are less delicate, and are of a rich blue-purple color.

Collections made by the writer in the same vicinity, and at other locations on the alluvial plains of central-western Washington, attest the validity of Heller's observations, although this segregate is less distinct than he supposed. *Camassia Quamash* subsp. *azurea* intergrades with the dark-flowered. *maxima* both on the north and the south. It differs from the latter primarily in respect to its habitat and such minor morphological characters associated with habitat as size and shape of bulb, and color and quality of bulb coats. The light flower color of subsp. *azurea* is a good field character, but in herbarium specimens the color may either fade or become intensified.

The floristic associates of subsp. *azurea* give evidence of its ecological adaptation to a dry habitat. A few miles north of Sheldon, Mason County, it is established on dry prairie dominated by the moss *Rhacomitrium canescens* which is well adapted to long periods of draught. Secondary elements of the flora are

Ranunculus occidentalis, Viola adunca, Luzula comosa, and the grasses *Festuca occidentalis, Koeleria cristata,* and *Aira praecox. Hypericum perforatum* has also invaded the area.

Representative specimens: WASHINGTON. King Co.: Snoqualmie, 1889 *E. C. Smith* (M). Mason Co.: Shelton, *G. N. Jones* 6495 (UW), *Gould* 1133. Jefferson Co.: lower Hoh River, *Murie* 1139 (M). Pierce Co.: Tacoma, *Thompson* 5141 (M,PA,S), 1908 *J. B. Flett* (UC); Roy, *Jones* 4640 (UW); Parkland, 1933 *Jones* (UW). Thurston Co.: Grand Mound, *Otis* 2063 (WS), *Gould* 1125, 1167; Olympia, 1906 *E. C. Townsend* (WS); Bakers Prairie, *Otis* 1829 (WS); Hawks Prairie, *Otis* 1840 (WS). Grays Harbor Co.: Montesano, *Heller & Heller* 3933 (M,PA), *Gould* 1132; Elma, *Otis* 2050 (WS), *Gould* 1131, *Jones* 6477 (CA,UW), 1919 *J. M. Grant* (M,NY); Aloha, *Jones* 6452 (UW); Oakville, *Gould* 1126. Lewis Co.: Forest Mountain, 1923 *V. M. Gessell* (WS).

4d. **Camassia quamash** (Pursh) Greene subsp. **intermedia,** subsp. nov.

Quamasia Walpolei Piper, Proc. Biol. Soc. Wash. **29**:81. 1916. (in part).
Camassia Walpolei Macbride, Contr. Gray Herb. n.s. **56**:14. 1918. (in part).

Folia angusta, 2.5-4.5 dm. longa, 0.6-1.3 cm. lata, semper utrinque viridia; pedicelli 0.7-2.0 cm. longi, inflexo-erecti; perianthii segmenta 2.0-3.5 cm. longa, 0.4-0.5 cm. lata, subcaeruleo-violacea, 5-7-nervia, exteriora interdum 3-nervia, post anthesin separatim marcescentia.

Leaves narrow, 2.5 to 4.5 dm. long, 0.6 to 1.3 cm. broad, uniformly green on both surfaces; scape 3.5 to 6.0 cm. tall; raceme loosely or densely 10- to 30-flowered; pedicels 0.7 to 2.0 cm. long, strongly incurving in fruit; flowers usually zygomorphic; perianth segments 2.0 to 3.5 cm. long, typically 5.0 mm. or less broad, usually with a short claw, pale blue-violet, 5- or 7-veined or inner whorl 3- and outer 5-veined, withering separately; anthers bright yellow 5.0 to 7.0 mm. long before dehiscence; capsules 1.0 to 1.5 cm. long, locules 6- to 10-seeded.

Type: OREGON. Douglas County: "One mile east of Sutherlin," May 7, 1940, *Gould 1102* (UC).

Range: Southern Lane County to central Douglas County, Oregon; regularly associated with the cream-white-flowered *C. Leichtlinii* subsp. *typica* in fields and pasturelands of the Umpqua Valley.

Camassia Quamash is represented in southwestern Oregon by two subspecies, subsp. *intermedia* and subsp. *Walpolei.* Both have pale blue flowers and non-connivent perianth segments and have been grouped together by Piper as *C. Walpolei.* In comparison with subsp. *Walpolei,* subsp. *intermedia* characteristically has larger, zygomorphic instead of regular flowers, relatively narrower but more numerously nerved perianth segments, larger capsules, longer leaves, and frequently longer pedicels. The two subspecies are separated geographically by the mountains of southern Douglas and northern Jackson and Josephine counties. No colonies of truly intermediate plants are known.

Subspecies *intermedia* intergrades with the dark-flowered subsp. *maxima* in southern Lane County. The change in flower color is accompanied by an

increase in width and body of the perianth segments, and a general increase in the size of the entire plant.

Representative specimens: OREGON. Lane Co.: *Gould* 1104. Douglas Co.: Drain, *Mason* 5293 (UC); Sutherlin, 1923 *L. E. Hunt* (WS), *Gould* 491, 1102; Roseburg, *Cusick* 3894 (WS), *Gould* 1093; Winchester, *Cusick* 4087 (WS); between Grants Pass and Corvallis, 1933 *Nelson & Nelson* (RM).

4e. **Camassia Quamash** (Pursh) Greene subsp. **Walpolei** (Piper), comb. nov.

Quamasia Walpolei Piper, Proc. Biol. Soc. Wash. **29**:81. 1916.
Camassia Walpolei Macbride, Contr. Gray Herb. n.s. **56**:14. 1918.

Leaves 1.5 to 3.5 dm. long, 0.4 to 1.3 cm. broad, uniformly green on both surfaces; scape 2.0 to 4.5 dm. tall; raceme densely flowered, the pedicels short, usually 0.5 to 1.0 cm. long, closely placed, and strongly incurving-erect in fruit; flowers small and with rare exceptions regular; perianth segments 1.2 to 2.0 cm. long, 0.3 to 0.5 cm. broad, pale blue or blue-violet, typically 3-veined or the inner whorl 3- and outer whorl 5-veined, withering separately; anthers bright yellow, 3.0 to 5.0 mm. long before dehiscence; capsules 0.8 to 1.2 cm. long, the locules 3- to 6-seeded.

Type: OREGON. Klamath County: "Klamath Agency, Wood River," June 22, 1902, *F. A. Walpole 2218* (US).

Range: Southwestern Oregon; in wet meadows at an altitude of from 500 to 5000 feet.

This is one of the best defined subspecies of *C. Quamash*. It is characterized by the possession of dense racemes of small, regular flowers, short, sub-equal pedicels, and small, few-seeded capsules.

Subspecies *Walpolei*, for the most part, is an ecotype of hilly or mountainous terrain, but also occurs on the plains of the Rogue River Valley in the vicinity of Grants Pass. It attains its best development in wet meadow habitats, but also frequents open woodlands bordering these areas. The writer has observed it both in scrub oak and open yellow pine forest. Typical plant associates in open meadow habitats are: *Ranunculus Bongardii*, *R. orthorhynchus*, *Plectrites macrocera*, *Limnanthes gracilis*, *Delphinium Menziesii*, and *Camassia Leichtlinii*.

The range of subsp. *Walpolei* is closely approached on the east by that of subsp. *breviflora*, both having been collected on the Klamath Indian Reservation, Klamath County, Oregon. (subsp. *Walpolei*, Klamath Agency, *Walpole 2218* (US); subsp. *breviflora*, 5 miles northeast of Kirk, *Gould 490*.) There is apparently no intergradation between these subspecies, although their separation is a matter of only a few miles and no apparent external barriers exist. Whether or not they are intersterile has not been determined, but it is possible that they are related only through their mutual northern relatives.

Representative specimens: OREGON. Klamath Co.: head of Denny Creek, west of Klamath Lake, *Applegate* 4661 (F,UC), 5421 (S), 3722 (S,UC); Klamath Agency,

Walpole 2218 (US); Klamath Valley, *H. M. Cronkhite* 16 (UC). Jackson Co.: Green Spring Mountain, *Applegate* 6151 (F,S,UC); 13 miles east of Ashland, *Gould* 779; Applegate Ranch, *Applegate* 6152 (S,UC); Siskiyou Summit, *Gillespie* 8290 (S), *Gould* 765; Siskiyou Camp, *Henderson* 12787 (UO); 17 miles east of Ashland, *Peck* 15012 (M). Josephine Co.: Waldo, *T. Howell* 1476 (NY), *Gillespie* 4619 (S), *Gould* 814, 1044; Merlin, *Henderson* 12452 (PA); Camp Caves, *Applegate* 7100 (S,UC), *Gould* 800; Takilma, *Henderson* 5990 (CA,M,RM,S); west of Grants Pass, *Gould* 1055, *Abrams, & Benson* 10392 (RM,S); 11 miles south of Grants Pass, *Mrs. N. P. Gale* 81 (M,PA); 5 miles north of Grants Pass, *Gould* 1064; Grants Pass, *Eastwood & Howell* 1657 (CA).

4f. **Camassia Quamash** (Pursh) Greene subsp. **linearis,** subsp. nov.

Folia angusta, 2.0-5.0 dm. longa, 0.6-1.5 cm. lata, semper utrinque viridia; pedicelli 1.0-2.5 cm. longi, inflexo-erecti; perianthii segmenta 2.0-3.5 cm. longa, 0.5-0.8 mm. lata, caeruleo-violacea, 5-9-nervia, exteriora interdum 3-nervia, post anthesin super capsulam conniventia; antherae subflavae ad violacea.

Leaves narrow, usually 2.0 to 5.0 dm. long, 0.6 to 1.5 cm. broad, uniformly

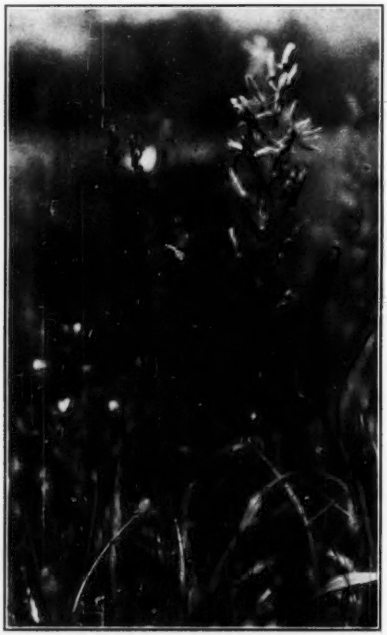

Fig. 8. Flowering raceme of *Camassia Leichtlinii* subsp. *Suksdorfii* and fruiting racemes of *C. Quamash* subsp. *Walpolei* in a wet meadow near Waldo, Oregon.

green on both surfaces; scape 2.5 to 8.0 dm. tall; pedicels 1.0 to 2.5 cm. long, incurving-erect in fruit; bracts broad, as long as or longer than the pedicels; flowers usually slightly zygomorphic; perianth segments 2.0 to 3.5 cm. long, 0.5 to 0.8 cm. broad, deep blue-violet, 5- to 9-veined or outer whorl 3-veined, connivent over capsule after anthesis and persistent on fruiting raceme; anthers dull yellow to violet, 4.0 to 7.0 mm. long.

Type: CALIFORNIA. Mendocino County: "1 mile southeast of Laytonville," May 5, 1940, *Gould 1040* (UC).

Range: northern coast ranges of California, Marin to Del Norte counties; in wet meadows from near sea-level to about 2500 feet altitude.

Two rather well-defined forms of this subspecies can be distinguished, the coastal phase at Point Reyes, Tomales Point, Albion, and Eureka, and the inland form found at Willits, Sherwood Valley, and Laytonville. In the coastal plants, pedicel length is exceedingly variable, frequently being as great as 2.5 cm.; the perianth segments wither with considerable body and remain conspicuously matter together on the fruiting raceme. They are, however, only weakly connivent over the capsule after anthesis and this characteristic is almost lost in some cases. In the inland form the pedicels are uniformly short, rarely exceeding 1.5 cm., and the perianth segments wither with little body and are usually strongly connivent over the capsule.

Subspecies *linearis* commonly grows in *Juncus-Carex-Ranunculus* associations in wet meadows that are covered by several inches of water during the spring months.

Representative specimens: CALIFORNIA. Humboldt Co.: Snow Camp, *Kildale* 10558 (S); Eureka, Tracy 3135 (UC), 1896 *Blasdale* (UC); Humboldt Hill, *Tracy* 2428 (RM,UC,UO); Burr Valley, Buck Mountain, *Tracy* 4152 (&C); Dinsmores, *Tracy* 2903 (UC); Garberville, 1931 *M. S. Jussel* (UC). Mendocino Co.: Sherwood Valley, *Davy* 5186 (UC), *Blasdale* 1036 (UC), *Gould* 1033; Willits, *Gould* 413, 1032; Albion, *J. McMurphy* 171 (NY), 1920 *M. Gabes* (S); Laytonville, *Gould* 1040; Glen Blair, *Eastwood & Howell* 2639 (CA). Lake Co.: Kelseyville, 1930 *Blankinship* (M). Napa Co.: St. Helena, 1921 *Mrs. C. Hunt* (CA). Sonoma Co.: Kenwood, 1893 *Michener & Bioletti* (NY); Occidental, *E. Armstrong* 1196 (VTM); Coast Road, *Baker* (1897) (UC). Marin Co.: Inverness, *Mason* 5225 (UC), *Gould* 395; Point Reyes, 1853-54 *Bigelow* (G,NY,UC), *Schrieber* 2508 (VTM), 1901 *Eastwood* (RM,UC,UO); Tomales Point, *Gould* 412.

4g. **Camassia Quamash** (Pursh) Greene subsp. **breviflora,** subsp. nov.

Folia comparte lata, 1.5-3.0 dm. longa, 1.0-1.7 cm. lata, in pagina adaxiallari glauca; pedicelli 0.5-1.5 cm. longi, inflexo-erecti; perianthii segmenta 1.5-2.0 cm. longa, 0.3-0.5 cm. lata, caeruleo-violaceae, 3-nervia, interiora interdum, exteriora rare 5-nervia, post anthesin super capsulam conniventia; antherae aureae.

Leaves usually 1.5 to 3.0 dm. long, 1.0 to 1.7 cm. broad, glaucous on adaxial surface; scape 2.0 to 5.0 dm. tall; pedicels 0.5 to 1.5 cm. long, incurving-erect in fruit; bracts as long as or longer than pedicels but usually narrow and inconspicuous; flowers small, at least some flowers of all racemes zygomorphic; perianth segments bright blue to deep blue-violet, typically 1.5 to 2.0 cm. long,

0.3 to 0.5 cm. broad, 3- or occasionally 5-veined, connivent over capsule after anthesis; anthers bright yellow, 0.4 to 5.0 mm. long.

Type: CALIFORNIA. Sierra County: "Hobart Mills, 7 miles north of Truckee," June 25, 1938, *Gould 436* (UC).

Range: Cascade Mountains of southern Washington, eastern Oregon, north

Fig. 9. a. *Camassia Quamash* subsp. *linearis* (left) and *C. Leichtlinii* subsp. *Suksdorfii* (right). Note the shape of the buds and the length of the pedicels. b. *C. Quamash* subsp. *linearis* (left) and *C. Leichtlinii* subsp. *Suksdorfii* (right). Note the zygomorphic flower of the former and the regular flowers of the latter.

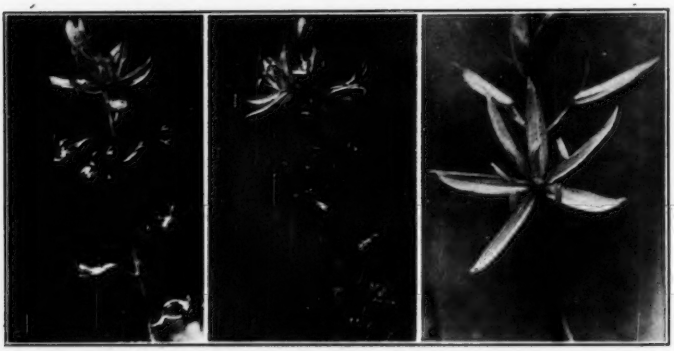

Fig. 10. a. and b. Flowering racemes of *Camassia Quamash* subsp. *breviflora*. Note zygomorphic flowers, connivent perianth segments, and short pedicels that become incurving as the fruit develops. c. *C. Quamash* subsp. *intermedia*. Note the long, narrow, clawed perianth segments and the flower zygomorphy.

cross ranges of California, and Sierra Nevada to Lake Tahoe region; in wet meadows at 2500 to 7000 feet altitude.

This small-flowered *Camassia* merges into *C. Quamash* subsp. *typica* in south-central and southeastern Washington, and is continued as a dark-flowered form of subsp. *typica* north to about Seattle. The key character of the connivence of the perianth segments is lost in the vicinity of Pullman, Washington. This change is accompanied by an increase in flower size, a darkening of anther color, and a general change in the appearance of the flowering raceme. Subspecies *breviflora* intergrades with subsp. *utahensis* in western Idaho and classification of plants in this vicinity must be rather arbitrary. A third line of relationship is with the large-flowered subsp. *linearis*. Subspecies *breviflora* reaches central Siskiyou County, California, in the northern cross ranges of the state, and subsp. *linearis* has been recorded from several localities in neighboring Humboldt County.

Representative specimens: WASHINGTON. Whitman Co.: Pullman, *Elmer* 223 (M,NY,WS). Asotin Co.: Anatone, *St. John & Palmer* 9661 (WS), 1936 *V. Gessell* (WS); Blue Mountains, *G. N. Jones* 1884 (WS). Garfield Co.: Clearwater Ranger Station, *Constance & Clements* 1719 (WS). Walla Walla Co.: 1896 *C. V. Piper* (NY); Waitsburg, *Horner* B481 (G). Klickitat Co.: between Goldendale and Centerville, *Applegate* 6790 (S,UC); between Cleveland and Goldendale near Rock Creek grade, *Applegate* 6785 (F,S,UC); Bingen, *J. W. Thompson* 8158 (M).

OREGON. Union Co.: Union, *Cusick* 3724 (WS); La Grande, *H. P. Hansen* 1207 (WIS). Gilliam Co.: Hoover Creek, *Leiberg* 128 (G,UC). Hood River Co.: *Henderson* 521 (of 1924) (M). Baker Co.: 8 miles north of Baker, *Applegate* 6255 (S). Grant Co.: Austin, *Applegate* 6228 (S); Austin Ranch, *Henderson* 5395 (CA,G,S, UO); Bates, *Eggleston* 22092 (US); Blue Mountain Ranger Station, *Constance & Beetle* 2720 (UC); Prairie City, *Beetle & Constance* 2625 (UC). Wheeler Co.: Mitchell, *Applegate* 6192 (F,S,UC); Fossil, 1894 *Leiberg* (UO). Malhour Co.: Cow Creek, east of Sheaville, *Henderson* 8830 (CA,UO). Harney Co.: Burns, *Henderson* 8832 (CA,G,M,UO); 20 miles south of Crane, *Henderson* 8831 (CA,UO). Lake Co.: Drews Valley, *Applegate* 5913 (S,UC); Camp Creek, 31 miles north of Lakeview, *Constance* (*Henderson* 9663) (UO,WS); Big Valley, *Mrs. C. C. Bruce* 2233 (UC). Klamath Co.: Swan Lake Valley, Brookside Ranch, *Applegate* 3526 (S,UC); Kirk, *Gould* 490.: "High Cascades," 1927 *J. H. Heckner* (PA).

NEVADA. Washoe Co.: 18 miles north of Reno, *Kennedy* 720 (M,RM,S); Lemmon Valley, *Kennedy* 2076 (M,PA,RM).

CALIFORNIA. Modoc Co.: Davis Creek, east side of Goose Lake Valley, *Applegate* 5897 (S); Parker Creek, east of Alturas, *Ferris* and *Duthie* 142 (S); Ft. Bidwell, *M. H. Manning* 145 (UC); Forestdale, *F. P. Nutting* ..... (UC), *M. S. Baker* .... (UC). Siskiyou Co.: Edgewood, 1927 *Heller* (M); Goosenest Mountain, *Eastwood* 959 (G,NY), *Gould* 1224, *C. D. Butler* 890 (S,UC). Lassen Co.: Ravendale, *Applegate* 8936 (S); Westwood, *Heller* 15140 (NY,S); between Susanville and Janesville, *Gillespie* 9390 (S); between Patterson Mountain, 1940 *A. Simontacchi* (VTM). Shasta Co.: Bear Creek *Hall & Babcock* 4160 (UC); Burney 1923 *E. Bethel* (CA). Plumas Co.: Drakesbad, *Parks & Parks* 220 (UC), *Applegate* 5810 (S,UC); Portola, *Eastwood* 7058 (CA); Prattville, 1906 A. L. Coombs (CA), 1892 *Brandegee* (UC), 1897 *M. E. Jones* (CA). Tehama Co.: Mineral, *Heller* 14572 (M,NY,S). Sierra Co.: Sierraville, *Gould* 437, *E. Sawyer* 180 (VTM); Webber Lake, *Kennedy & Doten* 149 (RM,S,UC); Salmon Lake, 1921 *H. M. Evans* (F). Nevada Co.: Truckee, *Mason* 3300 (UC). *Gould* 436, 1886 *Sonne* (UC). Placer Co.: Deer Park, *Eastwood* 400 (CA,G,M). El Dorado Co.: Tallac, 1895 *C. J. Fox, Jr.* (UC).

4h. **Camassia Quamash** (Pursh) Greene subsp. **utahensis,** subsp. nov.

Facies foliorum adaxillares glaucae; pedicelli 1.0-2.0 cm. longi, inflexo-erecti; perianthii segmenta 2.0-3.5 cm. longa, 0.3-0.6 cm. lata, plerumque subcaeruleo-violacea, 3-nervia, vel 5-nervia, post anthesin super capsulam conniventia; antherae subflavae ad violaceae.

Leaves 2.0 to 5.0 dm. long, 1.0 to 2.0 cm. broad, glaucous on adaxial surface; scape 2.5 to 7.0 dm. tall; pedicels 1.0 to 2.0 cm. long, incurving-erect in fruit; flowers usually zygomorphic; perianth segments pale blue-violet or at times dark, typically 2.0 to 3.0 cm. long, usually 3-veined but occasionally 5- or more-veined, connivent over capsule after anthesis; anthers dull yellow to violet.

Type: UTAH. Cache County: "12 miles up Blacksmith Canyon," June 5, 1932, *Bassett* and *Ruth Maguire 3265* (UC).

Range: Great Basin, southern Idaho and northeastern Utah, intergrading with subsp. *typica* in southwestern Montana.

Subspecies *utahensis* is distinguished from subsp. *breviflora,* with which it intergrades in western Idaho, by its larger, usually pale-blue flowers, relatively narrower perianth segments, and generally less compact habit (longer leaves and scape, and less densely flowered raceme). It differs from subsp. *typica* principally in the connivence of its perianth segments.

Representative specimens: MONTANA. Gallatin Co.: Sixteen-mile Creek, 1902 *W. W. Jones* (CA,M,RM,S). Beaverhead Co.: Lima, *Rydberg* 2610 (NY); Beaver Canyon, *Shear* 3060, 3063 (NY).

IDAHO. Freemont Co.: Ashton, *Nelson* 10087 (M,RM,UC); Rea, *Maguire* 17126 (IH); Pond's Resort, *R. J. Davis* (UI); St. Anthony, *R. Pickett* 85 (RM), *E. N. Quayle* 93 (RM,S); Island Park, 1930 *Davis* (UI). Clark Co.: 10 miles east of Kilgore, *Maguire* 17094 (IH), *A. Cronquist* 1374 (IH). Valley Co.: Cascade, *Davis* 1909 (UI). Adams Co.: Council, *Davis* 1967 (UI). Washington Co.: 15 miles east of Midvale, 1930 *A. E. Borell* (UC). Gem Co.: Sweet, *Macbride* 816 (CAN,G,IH, M, RM, S, UC, WS). Blaine Co.: Ketchum, 1892 *I. Mulford* (G,M,NY). Camas Co.: Corral, *Macbride & Payson* 2868 (CA,G,M,NY,RM,S,UC). Elmore Co.: ....., 1937 *Davis* (WS). Owyhee Co.: House Creek, *Nelson & Macbride* 1828 (G,IH,M, RM). Bannock Co.: Pocatello, *G. W. Spcerry* 24 (RM). Bear Lake Co.: Bear Lake, 1930 *Davis* (UI). Franklin Co.: summit between Preston and Grace, 1935 *Davis* (UI).

UTAH. Cache Co.: Blacksmith Canyon, *Maguire & Maguire* 3265 (IH,RM,UC); Logan, *Maguire* 3264 (IH,UC), *Maguire* 17119, 16710 (IH); Mendon, *C. P. Smith* 2134 (G,IH). Davis Co.: Farmington, 1908 *Mrs. J. Clements* (F,G,M,PA,S), 1881 *M. E. Jones* (CA,IH,NY,RM,UW,WS); Antelope Island, *Watson* 117v (NY). Summit Co.: Gogorza, *Garrett* 2929 (NY); Bear River, *Goodman* 390 (RM). Wasatch Co.: Midway, *Eastwood & Howell* 517 (CA); Strawberry Valley, *A. D. Smith* 166 (IH).

5. CAMASSIA CUSICKII Wats.

Camassia Cusickii Watson, Proc. Am. Acad. **22**:479. 1887.
Quamasia Cusickii Coville, Proc. Biol. Soc. Wash. **11**:64. 1897.

Bulbs large, clustered, 2.0 to 5.0 cm. in diameter, proportedly inedible; leaves 2.5 to 5.0 cm. long, 2.0 to 4.0 cm. broad, thick and rather succulent; scape stout, 5.0 to 8.0 dm. or more tall; pedicels 1.5 to 2.5 cm. or more long, incurving-erect or slightly spreading; flowers slightly zygomorphic; perianth segments pale blue or blue-violet, usually 2.5 to 3.5 cm. long, 3- or occasionally 5-nerved, withering separately at base of capsule after anthesis; capsules ovate or oblong, 1.5 to 2.5 cm. long.

Type: OREGON. Baker County: "Hillsides of the Snake River region," 1886, *W. C. Cusick 1445* (G).

Range: Wallowa Mountains, northeastern Oregon.

Watson (1887) expressed the known differences between *C. Cusickii* and the closely related *C. Quamash* when he stated:

> Very near *C. esculenta (C. Quamash)* in its essential characters, differing from it in its larger bulb, more numerous leaves, and stouter and more clustered habit, growing on hillsides instead of wet meadows, and the bulbs naseous, pungent, and inedible.

The habit distinction he noted is probably of slight importance in view of the high adaptability of *C. Quamash* ecotypes.

As far as is known, there have been no recent collections of *C. Cusickii*. Living bulbs of this species were obtained from Carl Purdy of Ukiah, California, but Mr. Purdy did not know from where they originally came, nor by whom they had been colected.

Representative specimens: OREGON. Baker Co.: Snake River region, *Cusick* 1445 (G,UO,WS), 1907 *Cusick* (G,M,UC).

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A New Species of Quercus in Texas

Cornelius H. Muller

In the course of preparing a descriptive review of the oaks of Texas a remarkably distinct new species of the series *Prinoideae* was discovered. Since the completion of that study is now being postponed, it was deemed desirable to place on record this clearly new endemic species.

The restriction of the range of this novelty to East Texas and its more than ordinarily robust stature have suggested for it the name of Texas' greatest leader. It seems particularly fitting that this species should be dedicated to General Sam Houston; it is proposed as a living monument that will last longer, it is hoped, than his inanimate memorials but not longer than his memory.

Quercus Houstoniana sp. nov.

Arbor grandis, ramuli 2-4 mm. crassi glabrati, gemmae 5-7 mm. longae ovoideae, folia decidua, 10-20 cm. longa, 5-10 cm. lata, obovata, margine repande dentata, apice acuta, basi rotundata vel cuneata, supra glabra, subtus villosi-tomentosa, venis utrinque 12-15 supra impressis, petioli 2-3 cm. longi, tarde glabrati, fructus annuus, brevi-pedunculatus vel subsessilis, cupula 2-4 cm. lata, 1.5-2 cm. alta, hemispherica, squamae laxe appressae, glans ovoidea, 1.5-3 cm. longa, 1.25-2.75 cm. lata, ½ inclusa.

Large tree. Twigs 2 to usually 3 or sometimes 4 mm. thick, shallowly fluted, from very sparsely villous becoming glabrate and reddish or grayish brown. Buds 5 to 7 mm. long, 2.5 to 4.5 mm. broad, acutely ovoid, brown, noticeably short-pubescent. Stipules about 8 mm. long, ligulate, pubescent, very promptly caducous. Leaves deciduous, 10 to 15 or even 20 cm. long, 5 to 8 or 10 cm. broad, obovate, apex usually acute, rarely rounded, base rounded or cuneate, blade repandly coarsely toothed or finely lobed, upper surface glabrous or sparsely pubescent along the midrib, somewhat lustrous, lower surface dull, finely short-villous-tomentose, or sparsely so, the blade white-punctate, appearing glaucous in sparsely pubescent forms; veins 12 to 15 on each side, each passing into a tooth or lobe, obscurely branching if at all, slightly impressed above, prominently raised beneath; petioles 2 to 3 cm. long, villous but usually glabrate in age. Staminate catkins? Pistillate catkins 5 to 10 mm. long, 1- to 3-flowered, tomentose. Fruit annual, large, solitary, paired, or ternate, subsessile or on a peduncle up to 20 mm. long and 4 mm. thick. Cups 2 to 4 cm. broad, 1.5 to 2 cm. deep, cup-shaped or hemispheric, the base rounded, margins thin, slightly roughened by projecting scale apices, scales very coarse, obviously thickened, triangular but the uppermost with narrowed apices, very loosely appressed, obviously spirally arranged, densely fulvous-puberulent all over. Acorns 1.5 to 3 cm. long, 1.25 to 2.75 cm. broad, broadly ovoid, the base flat, rounded at the apex, puberulent, about one-half included. (See Fig. 1.)

Quercus Houstoniana occurs commonly throughout the more mesic forests of East Texas. It is particularly prominent and important as a timber tree in

the Big Thicket area and in the river bottom forests of all the principal East Texas streams. Specimens in various herbaria have been examined as listed below.

TEXAS—HARRISON CO.: Marshall, September 26, 1915, *E. J. Palmer 8672* (AA). RUSK CO.: Concord, March 29, 1881, *C. S. Sargent without number* (AA). PANOLA

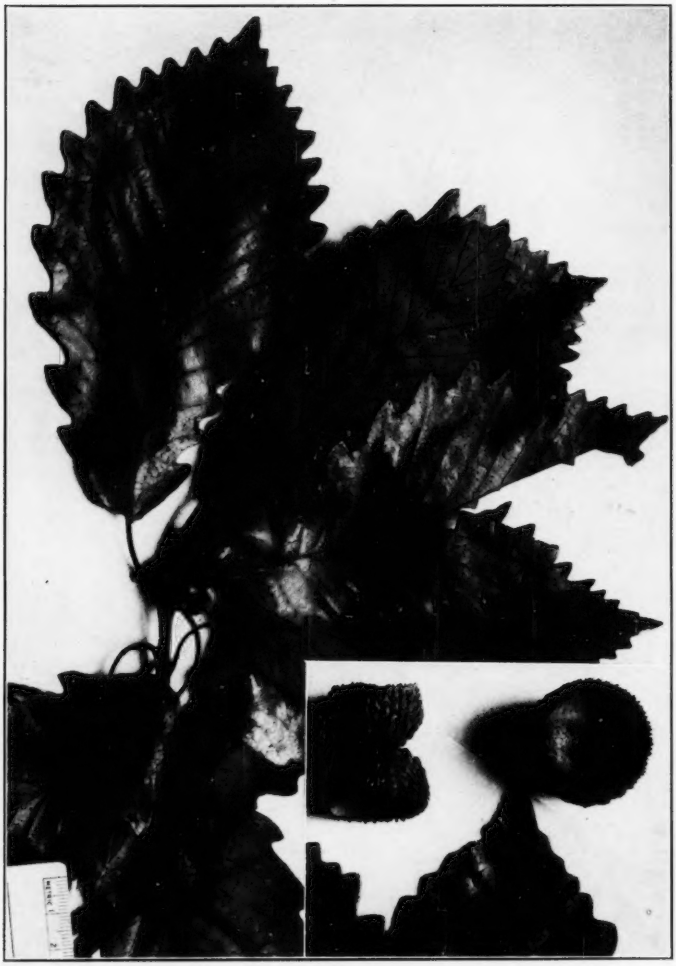

Fig. 1.—*Quercus Houstoniana* sp. nov.: San Augustine Co., *Palmer 12693* (AA—type). Inset: Angelina Co., *Boon* (T).

Co.: Sabine River, 8 mi. southwest of De Berry, July 2, 1941, *C. H. Muller 3888* and *3888A* (USNA). SAN AUGUSTINE Co.: San Augustine, April 19, 1916, *E. J. Palmer 9496* (AA); September 10, 1917, *E. J. Palmer 12693* (AA—type—, G, NY, US). ANGELINA Co.: Odell, Stanley Creek, Angelina River, August 13, 1934, *E. Boon without number* (T); Highway 35, Neches River, August 14, 1934, *E. Boon without number* (T); Angelina River, August 14, 1934, *E. Boon without number* (T); September 24, 1934, *E. Boon without number* (T, USNA); September 25, 1934, *E. Boon without number* (T). POLK Co.: Livingston, October 8, 1914, *E. J. Palmer 6771* (AA, US). HARDIN Co.: Saratoga, December 6, 1904, *V. Bailey 930* (US); Sour Lake, 1929, *J. L. Johnson without number* (T). LIBERTY Co.: without definite locality, October 27, 1901, *Bray* and *Ferguson without number* (T); Trinity River, October 27, 1901, *A. M. Ferguson without number* (T); "Blair's Mill," October 27, 1901, *Bray* and *Ferguson without number* (T); "Trinity River, Blair's Mill," November 1903, *W. L. Bray 9* (US); Dolen, April 18, 1914, *M. S. Young without number* (T); 2.5 mi. southeast of Cleveland, July 11, 1941, *C. H. Muller 3937* (USNA). SAN JACINTO Co.: 6.5 mi. north-northeast of Cleveland, July 11, 1941, *C. H. Muller 3939* (USNA); 12.8 mi. north-northeast of Cleveland, July 11, 1941, *C. H. Muller 3941* (USNA). MONTGOMERY Co.: near New Caney, October 26, 1901, *Bray* and *Ferguson 730* (T). JEFFERSON Co.: Neches River, Beaumont, April 22, 1916, *E. J. Palmer 9525* (AA); Beaumont, March 16, 1918, *E. J. Palmer 13082* (AA,NY,US). CHAMBERS Co.: 7 mi. north of Anahuac, July 11, 1941, *C. H. Muller 3934* (USNA). HARRIS Co.: Houston, July 25, 1915, *G. L. Fisher 1707* (US). BRAZORIA Co.: Chocolate Bayou, southwest of Alvin, December 6, 1918, *H. C. Hanson without number* (NY); Chocolate Bayou, September 14, 1933, *B. C. Tharp without number* (T).[1]

Quercus Houstoniana has long been confused with the other species of the series *Prinoideae*. Sargent in his Manual included it in *Q. Prinus* L. Small refers it in his Flora to *Q. acuminata* (Michx.) Houba and to *Q. Michauxii* Nutt., while in his Manual he places it in *Q. Prinus* and *Q. Muehlenbergii* Engelm. Trelease follows Sargent in referring the East Texas plant to *Q. Prinus*. Lewis (Bull. Univ. Texas 1915: No. 22) calls it *Q. Michauxii* and furnishes the vernacular names "Cow Oak" and "Basket Oak." From both the species to which these various names are now referred (*Q. Prinus* and *Q. Muehlenbergii*) *Q. Houstoniana* is readily separated by its petioles pubescent, leaves impressed-veiny above and persistently short-tomentose beneath, fruit large, the cup scales loosely appressed. Most herbarium specimens are sterile, but the pubescence of the petioles and lower leaf surface serves as an adequate distinction at nearly all stages of growth. *Q. Prinus* centers in the Atlantic States and does not extend as far west as the Mississippi River. *Q. Muehlenbergii* is most abundant in the Mississippii Valley and ranges westward through Texas. It enters Texas from the northeast and thence along the dry limestone escarpment of the Edwards Plateau to central and western Texas. This range is markedly distinct both geographically and ecologically from that of *Q. Houstoniana* which is confined to the moist forests of southeastern Texas.

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1 In the citations of specimens herbaria are indicated as follows: AA=Arnold Arboretum, Harvard University, Jamaica Plain, Mass. G=Gray Herbarium, Harvard University, Cambridge, Mass. NY=New York Botanical Garden, New York, N. Y. T=Texas University, Austin, Texas. US=U. S. National Museum, Washington, D.C. USNA=U.S. National Arboretum, Washington, D. C.

BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

A New Protoachlya[1]

Leland Shanor and Robert A. Conover

The genus *Protoachlya* was established in 1923 by Coker on *P. paradoxa,* a species which he had previously (Coker, 1914) assigned to the genus *Achlya.* The distinctiveness of this plant was clearly recognized when it was discovered, but at that time Coker preferred not to create a new genus for this one species. Further consideration, however, convinced him that it should not be retained in the genus *Achlya.*

A water sample collected in Brownfield Woods, Urbana, Illinois, October 18, 1941, was the source of the new species which we are reporting. Hemp seed placed in this water sample were luxuriantly covered with the very fine mycelium of a water mold two days later. Single spore and single hyphal cultures were made in order that the characteristics of this fungus could be carefully studied in pure culture. The cymose and internal proliferation of sporangia and the behavior of emerging zoospores in these cultures indicated that this fungus belonged to the genus *Protoachlya.* The typical hypogynous antheridia of this species establish our plant as new and prompt us to name it *P. hypogyna* sp. nov. The following description is drawn up from cultures growing on sterilized hemp seed in charcoal-treated, sterilized, distilled water.

Protoachlya hypogyna sp. nov.

Hyphae delicate, straight, very little branched, up to 40 μ in diameter at the base when growing on hemp seed, mostly much narrower, 12-20 μ, reaching a length of 1.5-2 cm. Sporangia numerous, subcylindrical to narrowly clavate, up to 330μ in length, largest at the distal end which is commonly about 20-35 μ in diameter, furnished with a distinct short papilla; secondary sporangia mostly formed by cymose branching below older ones, internal proliferation with secondary sporangia produced outside the older ones not at all uncommon; dictyosporangia rather rare. Spores diplanetic, on emerging all ciliated, some swimming away, others remaining attached at the tip of the sporangia, encysting in an irregular clump. Gemmae not uncommon, usually spherical or more or less elongate, sometimes in chains. Oogonia produced at tip of short lateral branches or intercalary, usually roughly spherical, 28-72 μ in diameter, sometimes elongate, especially when formed within empty sporangia, unpitted, wall hyaline, usually smooth, occasionally with a few short papillate outgrowths, inner wall contour often irregular or warted; oospores centric, usually one or two, occasionally three, very rarely four or five, measuring 20-42 μ in diameter, mostly between 30-32 μ; antheridia usually cut off

1 We wish to thank Professors W. C. Coker and J. N. Couch for the loan of a slide of authentic material of *Achlya hypogyna;* for a living culture of *Protoachlya paradoxa* which we have used for comparison with this species; and for their critical reading of the manuscript.

from oogonial stalk immediately below the oogonium, rarely absent, antheridial branches sometimes arising from oogonial stalk or from the main hypha, occasionally diclinous, the short clavate antheridia in these cases being appressed to the sides of oogonia; fertilization tubes prominent, usually penetrating the septum between the oogonium and the hypogynous antheridium.

Hyphae tenues, ramosae, usque ad 2 cm. longae. Sporangia sub-cylindrica aut anguste clavata, usque ad 330 μ longa. Gemmae sphaericae aut cylindratae. Oogonia in ramis brevibus et lateralibus aut intercalaria, subglobosa, 28-72 μ diam.; tunica epunctulata, hyalina, levis aut cum paucis papillis brevibus. Oosporae centricae, 1-5 (plerumque 1-2) per oogonium, 20-43 μ diam. (plerumque 30-32 μ). Antheridia hypogyna, aliquando androgyna aut diclina.

Collected in water standing in a wet weather pool under trees in Brownfield Woods, Urbana, Illinois, October 18, 1941.

This plant is easily distinguished from *Protoachlya paradoxa* by its hypogynous antheridia and by the predominant number of oogonia containing only one or two oospores.

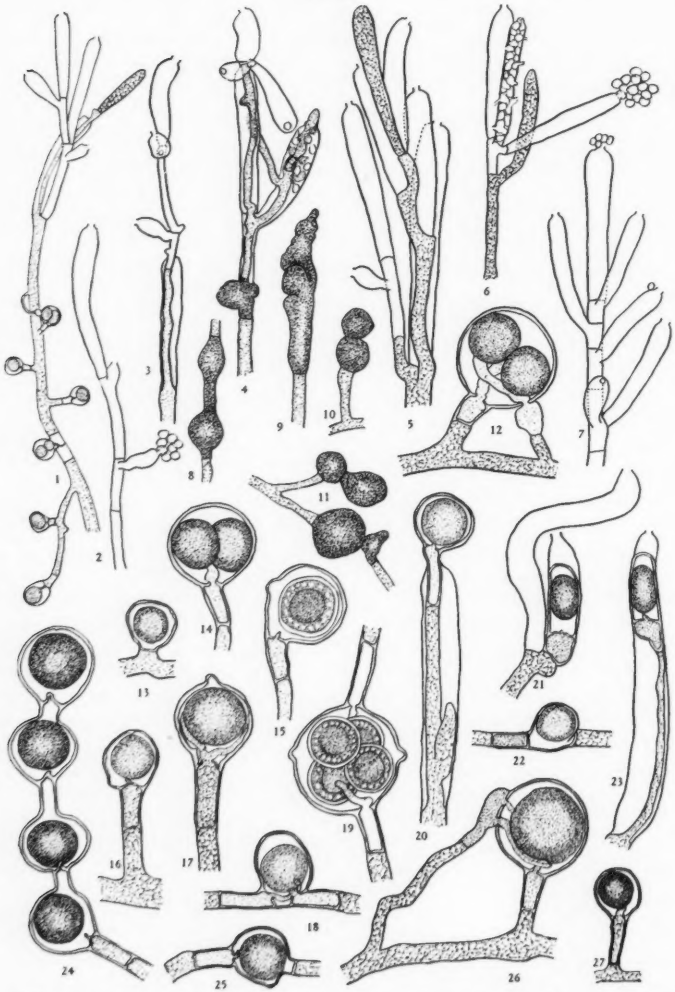
Slides of preserved material from type cultures are being deposited in the herbaria of the University of Illinois, the University of North Carolina, the University of Michigan, the Farlow Herbarium of Harvard University, and in the Mycological Collection of the Bureau of Plant Industry, Washington, D. C.

OBSERVATIONS

As Coker (1923) has stated for *Protoachlya paradoxa*, the method of sporangial formation in the genus is truly remarkable. Sporangia are produced abundantly by *P. hypogyna* and at first proliferate in the cymose manner typical of *Achlya*. Many of the later sporangia are formed by internal proliferation as is typical for *Saprolegnia*, but in these cases sporangia are very seldom delimited until the proliferating hypha has reached the outside of the empty sporangium (Fig. 1-4). The proliferating hyphae often give rise to several cymosely arranged sporangia at their tips (Fig. 4).

The behavior of the spores in *Protoachlya hypogyna* is variable. As spores leave sporangia they may encyst at once, as is typical of *Achlya*, or swim away to encyst some distance from the sporangial orifice. All spores stained and observed at the time of emergence were found to possess two anteriorly attached cilia. The spores that encyst at the mouth of the sporangium in an irregular clump usually show at least slight motility before becoming motionless. This slight movement is probably comparable to the rocking motion described for certain of the emerging spores of *Achlya hypogyna* (Coker and Pemberton, 1908; Coker, 1923). Spores discharged from many of the sporangia swim away rapidly upon emergence just as do the spores of *Saprolegnia*, while the behavior of others is more sluggish. The sporangia arranged in a cymose fashion whose spores swam away immediately strongly suggested an *Isoachlya*, but the fact that many spores encyst as in *Achlya* prevent the inclusion of our plant in that genus. In a number of the cases observed, part of the spores emerging from a sporangium swam away sluggishly while the remaining ones encysted at its

PLATE I



All figures drawn with the aid of a Spencer camera lucida. The approximate magnifications of these reproductions are as follows: Fig. 1, ×59; Figs. 2-11, ×127; Figs. 12-27, ×250.

Fig. 1. Portion of a hypha bearing oogonia, antheridia, and sporangia. Fig. 2. Tip of hypha with three sporangia. Fig. 3. Empty sporangium through which the hypha has

mouth or within it. Dictyosporangia have been observed occasionally but these are rather uncommon.

The majority of the oogonia of *Protoachlya hypogyna* are formed on the ends of short branches from the main hyphae (Figs. 12-17, 26-27), but many of them are intercalary (Figs. 18, 25), while others have an intercalary oogonial stalk (Figs. 18, 20). Occasionally oogonia may be formed in chains (Fig. 24). Their shape is predominantly spherical but usually asymmetrical. Elongate oogonia formed within empty sporangia are not infrequently encountered (Figs. 21, 23). Oogonia containing a single egg occur most abundantly, but those containing two eggs are not infrequent. Those with three eggs are rare, and we have observed oogonia with four or more eggs on only a few occasions in dozens of cultures examined. The oogonial walls are usually smooth to somewhat angled but occasionally small papillose outgrowths have been observed. The papillae on the oogonia shown in figures 15, 17, and 19 were about as prominent as any we have seen. The development of these papillae is no more pronounced when the fungus is grown on agar, on housefly grubs, or on other substrata than when cultured on hemp seed. The oogonial wall is seldom of a uniform thickness so that the inner surface of the wall is often somewhat irregular (Figs. 13, 16, 17). In some oogonia this inner wall is so abruptly thick in places that the thickened areas appear as warts (Figs. 16, 17, 24). The walls of mature oogonia are hyaline.

Hypogynous antheridial cells are present below almost all of the oogonia but it is probable that these are non-functional in some cases. A number of examples have been observed where this cell was still full of protoplasm when the eggs were almost mature. Fertilization tubes grow up through the septum into the oogonium in most cases, even though they may be non-functional. Antheridial branches originating on the oogonial stalk or from the hypha from which it arose (Figs. 12, 26) have been observed a number of times and those of a diclinous origin have been seen on several occasions. The antheridia are short clavate or somewhat tuberous in these cases and the fertilization tubes entering the oogonia from them are quite obvious.

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proliferated to form sporangia outside. Fig. 4. Group of sporangia showing both lateral and internal proliferation, and an intercalary gemma. Figs. 5-7. Portions of hyphae bearing groups of sporangia. A typical dictyosporangium is shown in Fig. 6. Figs. 8-11. Groups of typical gemmae. Fig. 12 and 26. Ooogonia with both hypogynous and androgynous antheridia. Note that fertilization tubes are formed from both types of antheridia in each case. Fig. 13. Oogonium with a parthenogenetic oospore. Figs. 14-17, 27. Typical oogonia with hypogynous antheridia as formed on short lateral branches. Short papillae are present on oogonia shown in Figs. 15 and 17. Note the general uneven thickness of oogonial walls with wart-like thickenings on inner surface of oogonia shown in Figs. 16 and 17. Figs. 18, 22. Ooogonia with intercalary stalks and intercalary antheridia. Figs. 19, 25. Intercalary oogonia and antheridia. Note short papillae on oogonium shown in Fig. 19. Oogonia with as many as four oospores are rare. Fig. 20. An empty sporangium with hypha proliferating internally bearing a terminal oogonium formed just outside the sporangial orifice. Figs. 21, 23. Two cylindrical oogonia with hypogynous antheridia formed within empty sporangia. Fig. 24. One terminal oogonium, three intercalary oogonia, and one intercalary antheridium formed in a chain.

The behavior of emerging zoospores and the combination of both *Achlya* and *Saprolegnia* types of sporangial proliferation would effectively separate *P. hypogyna* from *S. hypogyna* and *A. hypogyna*. The hypogynous type of antheridia observed for this *Protoachlya* is the predominant type in only these three species in the Saprolegniaceae. *Saprolegnia hypogyna* oogonia are readily distinguished by the distinct pits in the oogonial walls. The oogonia of *Protoachlya hypognya* resemble more closely those of *Achlya hypogyna* and we wish to emphasize that these two plants are very similar and obviously closely related. The two plants can be readily distinguished on the following oogonial characteristics:

Protoachlya hypogyna

1. Papillose outgrowths of oogonia short and on a relatively small percentage of oogonia.
2. Number of eggs per oogonium usually one or two, rarely more, average diameter of eggs 30-32 μ.
3. Intercalary oogonia common, occasionally in chains.
4. Mature oogonial walls hyaline.
5. Contour of inner surface of oogonial wall often irregular or even warted so that walls are rather uneven in thickness.

Achlya hypogyna

1. Papillose projections of oogonia usually very prominent and on most of the oogonia.
2. Number of eggs per oogonium usually three to five (those with only one or two not uncommon, however), average diameter of eggs 27-28 μ.
3. Intercalary oogonia rare.
4. Mature oogonial walls yellowish.
5. Contour of inner oogonial wall smooth and walls of a relatively even thickness.

DISCUSSION

Lounsbury (1930), investigating *Protoachlya paradoxa*, has shown that the combination of the *Achlya* and *Saprolegnia* methods of spore discharge which characterize the genus is not manifest under different conditions of the environment but is a physiologically stable behavior. *Protoachlya paradoxa*, therefore, is not a species either of *Saprolegnia* or of *Achlya* which discharges its spores in an atypical manner when environmental conditions are altered, as its characteristics might indicate.

Coker (1923) suggests that the genus may represent a possible ancestral form for several of the other genera of the *Saprolegniaceae* and remarks that the relationships of the genus (then represented by *P. paradoxa* only) are not obvious. He suggests, however, that *Dictyuchus* or the Racemosa Group of *Achlya* seem nearest. It might be mentioned here with reference to the relationships of the genus to *Dictyuchus*, that Apinis (1930) considers as a *Protoachlya* a plant which he thinks the same as that referred to in the earlier literature under the binomial *Dictyuchus polysporus*. If this identification by Apinis is correct, then the remaining species in the genus *Dictyuchus* form a more uniform group as Coker and Matthews (1937) state.

The characteristics of *Protoachlya hypogyna* suggest a close relationship to the Rocemosa Group of *Achlya* or more remotely to the Hypogyna Group of *Saprolegnia*. It is possible that both of these genera might have evolved from *Protoachlya* with *P. hypogyna* as a likely ancestral form. The discovery of *P. hypogyna* emphasizes Coker's hypothesis that the characteristics of *Protoachlya*

make this genus especially important from the standpoint of speculation as to the possible phylogeny within the Saprolegniaceae.

SUMMARY

1. A new species of *Protoachlya* is described as *P. hypogyna*. This species is characterized by having spore behavior and sporangial formation typical of the genus; a hypogynous antheridial cell below most oogonia; normally only one or two eggs in the oogonium; and a hyaline oogonial wall usually of a rather uneven thickness.

2. The probable relationships of this form and its possible phylogenetic importance in the Saprolegniaceae are discussed.

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Additions to and Comments upon the Lichen Flora of the Santa Cruz Peninsula, California

Albert W. C. T. Herre

In 1908, after eight years of field and laboratory work, I wrote my Lichen Flora of the Santa Cruz Peninsula, California, which was published in 1910. During the intervening years I have spent most of my time in far distant regions. In recent years it has been possible to collect or study lichens only at brief and infrequent intervals, yet casual collecting has shown that our knowledge of the lichens of the Santa Cruz Peninsula is by no means complete.

My Lichen Flora contained 321 species and subspecies or varieties worthy of description or special mention. Sixteen additional species were described in the Supplement, making a total of 337. Since that time two new species were described by Fink, *ex* Hedrick, and various others collected lichens and published on them. The list here given includes all except certain Cladonias which I do not recognize, and also my own recent additions. This adds 36 more, making a total to date of 373. We may be confident that further collections will increase this number materially, at least to 400.

The Santa Cruz Peninsula has such variations in rainfall, sunshine, fog, temperature, and substratum that it is divided into several marked life zones. It therefore affords a habitat to lichens characteristic of cold or alpine regions, and in its frostless belt to those from warmer regions. Accordingly it contains a curious assemblage of lichens, with some extraordinary and unexpected omissions from its lichen flora.

In studying lichens sent me for determination from all over North and South America during the past ten years, and especially in studying the local forms, I have constantly borne in mind that lichens are plastic organisms highly responsive to environmental factors. The tendency has been for many writers, especially in Europe, to look upon a species as a fixed entity, with sharply defined characters which can vary only within very narrow limits. To such writers the individuals comprising a species are like the units in a paper of pins, all alike. They forget that even machine made pins may vary at times. Variations in the metallic alloy, in its composition, temperature, and other factors, may and often do produce pins unlike their fellows. Many times one may note variations, even extreme ones, in a single widespread colony of *Lecanora, Lecidea, Diploschistes, Parmelia,* or *Cladonia.* As the colony spreads over different substrata, and various parts have more or less exposure to sun or shade, with consequent differences in the available water supply, one may note the transformation of the various extensions of the thallus into this or that variety or "species." It is true that several species of lichens often grow in inextricable confusion, with some kinds running over others, but it is likewise often true that one may trace a widespread growth from its original starting point, and note its variations as already indicated.

When I was writing my Flora all Cladonias were submitted to Drs. Bruce Fink, H. E. Hasse, and A. Zahlbruckner for their opinion; a few specimens were also sent to other Europeans and to Dr. W. C. Farlow, who had himself collected Cladonias in the Santa Cruz Mountains. In a number of cases, all disagreed in their determinations, and Dr. Fink and Dr. Zahlbruckner were unable to name several specimens at all. Mr. Blake collected some Cladonias in the Santa Cruz Peninsula several years ago and these were reported on in a paper by Robbins. In this paper several varieties previously noted in my Lichen Flora were made species, and the splitting of species carried to a degree which I cannot follow. Writers in the eastern United States and Europe, knowing west coast species from a few herbarium specimens only, and having very narrow and rigid ideas of species, have elevated to specific rank forms that are hardly worthy varietal designation. An illustration is *Pseudocyphellaria anomala* H. Magnusson. This is only a sorediate condition of *Sticta anthraspis* Ach. I have examined thousands of living specimens of *Sticta anthraspis*, in California, Oregon, Washington, and British Columbia. Large clumps of this lichen cover the tree trunks in some localities, single specimens often being ten or twelve inches in diameter. From one such huge complicated specimen one may get two "species" by selecting the proper thalline lobes.

Another case in point involves *Lecanora bolanderi* and *Lecanora thamnitis* of Tuckerman. These herbarium species are repeated in Fink's Lichen Flora, but both occur in a single growing clump. An examination of specimens at the type locality revealed that a single colony showed every gradation from extreme *bolanderi* to extreme *thamnitis*. Had Tuckerman, an able field worker, ever seen the plants growing, he would never have created *L. thamnitis*.

Various correspondents have sent me a *Cyphelium* growing on old fences, which they have called *farlowi*, following Fink. *Cyphelium farlowi* was collected by Dr. W. G. Farlow on maritime rocks at Monterey, California, and was named but never published by Tuckerman. It has never been collected since, the original locality having been eliminated by the growth of Monterey and Pacific Grove. What my correspondents have sent is *Cyphelium occidentale* Herre, which occurs on fences and old wood from California to Washington and is omitted by Fink. The *Cyphelium farlowi* of Fink is not that species at all; it seems to be an inadequate description of *Cyphelium occidentale*.

The following species are not in my Lichen Flora and Supplement:

1. ARTHOPYRENIA LITORALIS Arnold—On the shells of limpets and other mollusca, and on barnacles, at San Francisco and southward along the coast.
2. PYRENULA HERREI Fink *ex* Hedrick—On smooth barked oaks in the foothills.
3. SPHAEROPHORUS FRAGILIS (L.) Persoon—On rocks, Mt. San Bruno, at 1100 feet, and on maritime cliffs, Point San Pedro, San Mateo County. Specimens sterile.
4. ARTHONIA IMPOLITA (Ehrh.) Borrer—On Quercus agrifolia at Reid Oaks, near Aromas.
5. SCLEROPHYTON OCCIDENTALUM Herre.—On oaks near Los Gatos.
6. PECCANIA ARIZONICA (Tuck.) Herre—*Omphalaria arizonica* Tuck. *herb.*—Specimens sterile. On earth between rocks, in the foothills. This species has been omitted from Zahlbruckner's Catalogus Lichenum Universalis, and from Fink's Lichen Flora.

Tuckerman named but did not describe the species, which he had from Arizona and either New Mexico or Texas. Through the kindness of Dr. W. G. Farlow I received a specimen, named by Tuckerman and marked in his handwriting "spores 8, subglobose, 0.75μ." This specimen I used in naming material collected near Reno, Nevada, and near Stanford University, California. Unfortunately, during my absence from the United States for some years my largest box of lichens was destroyed; in it were many irreplaceable specimens, including those of *Peccania arizonica* named by Tuckerman.

7. NEPHROMA LAEVIGATUM Ach.—On various trees in dense woods.
8. PELTIGERA VENOSA (L.) Baumg.—On earth along the summit at King's Mt.
9. PELTIGERA SPURIA (Ach.) DC.—On soil in forests in the mountains.
10. LECIDEA CADUBRIAE (Mass.) Nyl.—On *Umbellularia californica*, Loma Prieta, at 3600 feet. Spores $\frac{3-3.5}{6-8}$ μ.
11. LECIDEA CARNULENTA (Tuck.) Fink—On bark of *Acacia*, Laveaga Park, Santa Cruz. Paraphyses conglutinate or subglutinate; spores $\frac{2.5-3.5}{6.5-11.5}$ μ.

    Specimens close to *Lecidea nigroclavata* Nyl.
12. LECIDEA CINNABARINA Sommerf.—Occasional on alders.
13. LECIDEA FUSCESCENS Sommerf.—On various trees, Loma Prieta, at 3600 feet. Spores nearly spherical, 6.2 to 9.3 mm. in diameter, and also short ellipsoid, $\frac{7.75-9.3}{9.3-12}$ μ.
14. LECIDEA LURIDELLA Tuck.—On sandstone on a ridge beside highway 152, 4 miles west of Gilroy.
15. LECIDEA POLYCARPA Floerke—Along the summit of the range; agreeing with material from the Austrian Alps.
16. LECIDEA RUSSULA Ach.—On trees, Stanford University.
17. CATILLARIA ATROPURPUREA (Schaerer) Th. Fr.—On bark of trees in the foothills near Stanford University. Spores $\frac{4.5-6.25}{12-15.5}$ μ.
18. CATILLARIA GLAUCONIGRANS Tuck.) Hasse—On *Cupressus*, Stanford University.
19. CATILLARIA PRASINA (E. Fr.) Th. Fr.—On *Acacia* bark, Laveaga Park, Santa Cruz. Spores rarely septate, $\frac{2.5-4.5}{7.5-12.8}$ μ.
20. BACIDIA ATROGRISEA (Hepp) Koerber—Laveaga Park, Santa Cruz, and in the mountains. Spores 7-14 locular, $\frac{2-4.6}{31-50}$ μ.
21. CLADONIA DEFORMIS (L.) Hoffman—Mountains east of Los Gatos, at 1800 feet.
22. CLADONIA DEGENERANS (Floerke) Sprengel—Both *f. cladomorpha* (Ach.) Wainio, and *f. phyllophora* (Ehrh.) Flot. occur in the mountains.
23. CLADONIA GRACILIS (L.) Willd.—Along summit of range.
24. CLADONIA HERREI Fink *ex* Hedrick—As yet only known from a sandstone cliff in Pilarcitos Creek Canon, San Mateo County.
25. CLADONIA PITYRAEA (Floerke) Fries—On earth in the foothills.
26. PERTUSARIA MULTIPUNCTA (Turner) Nylander—On oaks in the range above Woodside, altitude about 2200 feet. Spores solitary, $\frac{40-53}{108-155}$ μ.
27. LECANORA CONTORTA (Hoffm.) Stiz.—Not rare, especially along the sea coast.

28. LECANORA LAEVATA (Ach.) Nyl.—Hidden Villa Cañon.

29. LECANORA MUTABILIS (Ach.) Nyl.—On oak bark on Loma Prieta, at 3700 feet. Spores $\frac{25-31}{40-49}$ μ.

30. LECANORA POLYTROPA (Ehrh.) Rabenh.—Specimens scanty; occurring very sparingly on calcareous rock at the quarry, Calera, San Mateo County.

31. OCHROLECHIA PARELLA (L.) Mass.—On oaks near summit of Loma Prieta, at 3700 feet, and northward in the coast ranges through Oregon and Washington. Not in Fink. No reaction with KOH or $CaCl_2O_2$, singly or together.

32. PARMELIA CETRARIOIDES Delise—Frequent on trees along the summit of the range and on great sandstone cliffs.

33. CALOPLACA MICROPHYLLINA (Tuck.) Hasse—On twigs and limbs of trees in the hills east of Los Gatos, at 1200 feet.

34. BUELLIA PENICHRA (Tuck.) Hasse—At Laveaga Park, Santa Cruz. Thallus white; spores 1, 2, 3, 4, or 5 in the asci, and measuring $\frac{10-13}{14-23}$ μ. Fink gives the spores as 6-8, but my specimens from California and Washington are as above.

35. BUELLIA SEMITENSIS Tuck.—Castie Rock; at 3000 feet.

36. PHYSCIA CALLOSA Nylander—On rocks, summit of Twin Peaks, San Francisco.

37. ARTHONIA GREGARIA (Weig.) Koerber.—On *Alnus*, Hoover Ranch, Waddell Creek, Santa Cruz County. Spores 3 to 5 locular, measuring 6-9.3 by 18 to 25 μ.

38. OPEGRAPHA BETULINA J. E. Smith. On alders and willows along the Waddell Creek, Hoover Ranch, Santa Cruz County. Spores 4-locular, 6 to 7.75 by 20 to 25 μ.

This makes a total of 375 lichen species known from the Santa Cruz Peninsula, California.

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The Mycelium of the Uredinales

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Clamp-connections have come to be regarded as characteristic structures of the Basidiomycetes although they are lacking in many species. Some years ago the Moreau's (1922) reported them as occurring in the Ascolichen, *Parmelia Acetabulum*, but their figures are not convincing. More recently Greis (1938) reported them in a species of *Tuber*. If this report is correct it may be highly significant, but it should be verified.

With the exception of Clements and Shear (1931) and Bessey (1935) all modern mycologists include the rusts among the Basidiomycetes. With the recognition of the close relationship of the rusts to the Auriculariaceae there has been an increasing tendency to recognize Patouillard's sub-class Heterobasidiomycetes, embracing, besides the rusts, the smuts and the tremellaceous fungi, including the Dacrymycetaceae. Clamp-connections have been reported a number of times in the smuts (Stakman and Christensen, 1927; Hanna, 1929; Seyfert, 1929) and they have been seen in all families of the Tremellales except the Septobasidiaceae (Martin, 1942). The Septobasidiaceae, like the Uredinales, is composed of obligate parasites (Couch, 1939), and it is interesting to note that in the specialized parasitic genera of the Tremellales, such as *Jola* (Gäumann, 1922) and *Eocronartium* (Fitzpatrick, 1918) clamp-connections are likewise lacking. Nearly forty years ago Voss (1903) reported clamp-connections in the rusts. His results have never been verified and have not been generally accepted, but since the matter is still uncertain it has seemed desirable to investigate the mycelium of the rusts more fully.

Voss studied the aecial mycelium of *Puccinia graminis;* of *Puccinia* on *Carex hirta*, on *Carex acuta*, and on *Phragmites;* and of *Melampsora* on *Salix viminalis* and on *Salix pentandra*. He also studied the uredinial mycelium of *Puccinia graminis*, of *Puccinia* on *Carex acuta*, of *Puccinia* on *Carex hirta*, and of *Phragmidium violaceum*. He reports the observation of typical clamp-connections in all the species studied, and he has included drawings of the mycelium of several of the species of *Puccinia* and of *Phragmidium* in which these structures are shown.

At the time of his writing, the present interpretation of clamp-connections was unknown, and his description of their formation is therefore incorrect according to more recent investigations. As discussed by Voss, the formation of clamp-connections was merely a special case of hyphal anastomosis. This is in accord with Buller's interpretation (1933) of these structures. Voss considered clamp formation as a process in which a wide plasma bridge is laid down between two cells, as a result of the fusion of the clamp hypha with the cell next to that from which it sprang. This bridge, through the growth of a ring wall around it, becomes increasingly narrower until the wall closes completely

and the bridge is shut off from one cell. It is now known that this septum to which he refers is laid down soon after the protrusion of the short clamp hypha, before its fusion with the old cell. The structures observed and illustrated by Voss, which he considered to be still open clamps, could therefore represent no possible stage in the process as it is now known. Formations similar to those reported by Voss were also evident in the present study, but were necessarily interpreted differently. Besides representatives of the genera *Puccinia* and *Melampsora*, studied by Voss, other genera were included.

The following species were examined:

Pucciniastrum Agrimoniae—uredinial and telial stages on leaves of *Agrimonia gryposepala.*

Coleosporium Solidaginis—uredinial stage on leaves of *Solidago canadensis.*

Melampsora Medusae—uredinial and telial stages on leaves of *Populus deltoides.*

Tranzschelia Pruni-spinosae—telial stage on leaves of *Prunus serotina.*

Puccinia Malvacearum—telial stage on leaves of *Althaea rosea.*

It appeared desirable to devise a treatment by which as large a mycelial mass as possible could be observed completely, unobstructed by the cells of the leaf. This was brought about by removing the cellulose and pectic materials from the host cells and treating the leaf sections in such a manner that the mycelium of the fungus could be freed from the host tissue. The process used was as follows:

Leaves bearing sori of the above-mentioned species were killed and fixed in formal-acetic-alcohol and kept there until needed. The pieces were then washed in 50% alcohol and in distilled water and free-hand sections were cut through the sori. The sections were placed in cupra-ammonium hydroxide solution in a small covered watch glass and left in the refrigerator for about forty-eight hours to remove the cellulose from the leaf. They were then washed in 10% acetic acid followed by distilled water, and heated in a saturated solution of potassium oxalate for from twenty-five to thirty minutes. Testing with ruthenium red showed that the pectic materials had been removed from the leaf cells. After another washing in distilled water the sections were placed in a small uncovered beaker about one-third full of 10% potassium hydroxide, which was put on a previously warmed hot plate and allowed to heat for about eight minutes, boiling occurring during the latter part of the period. The length of time in potassium hydroxide varied slightly with the species, depending on the toughness of the leaf. With *P. Malvacearum* it was continued until the large sori had dropped loose from the leaf tissue, but in the other species the only indication of sufficient treatment in potassium hydroxide was the transparency of the sections. Too prolonged treatment resulted in a breaking up of the protoplasmic content of the hyphae so that definite staining of the septa was impossible. Sections treated in potassium hydroxide were then

removed from the hot solution with a pipette and placed in a watch glass of distilled water, and then into 5% hydrochloric acid. Sori with attached mycelium shaken loose during these processes were carefully watched for since they often afforded excellent material for study. Several stains were tried, including Delafield's Haematoxylin and cotton blue, but eosin in clove oil was found to be the most successful. The loose sori and sections with sori still attached were washed in tap water and dehydrated in 50%, 95%, and absolute alcohol, in which they were allowed to remain until stained. Several of the sections were placed on a slide at one time and stained for two or three minutes in several drops of a saturated solution of eosin in clove oil. The slide was then flooded with a mixture of equal parts xylol and absolute alcohol, then with xylol, and the sections were mounted in Clarite thinned with xylol and were crushed by immediately tapping the cover glass, in order to shake the mycelium as free of the host cells as possible. This treatment resulted, in many cases, in a permanent slide showing a large, tangled mass of mycelium with the spores still attached but unobscured by the host cells. A single hypha could therefore be followed for some distance and the cross walls easily observed.

Fresh mounts prepared by lifting a sorus from a section of the same leaves, which had been killed and preserved in formal-acetic-alcohol and washed in water, were mounted in 3% potassium hydroxide and stained with phloxine. These served as a check on the permanent slides. Drawings were made with the aid of a camera lucida from both the permanent slides and the fresh mounts.

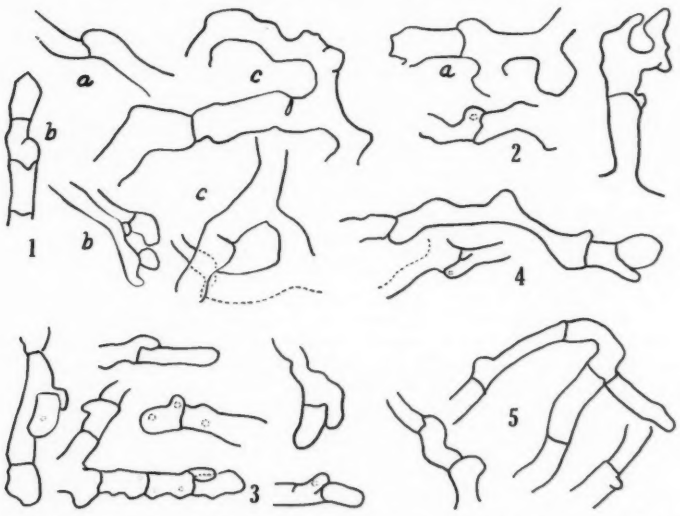
The mycelium of all the species studied was much-branched and very irregular, varying greatly in thickness, even, in some cases, from cell to cell. The cells themselves were irregularly shaped and contained a number of bulges and protuberances, particularly at the septa, which might easily be mistaken for clamp-connections.

Puccinia Malvacearum was the species studied with the least difficulty because of the ease with which the free mycelium could be obtained. The softness of the hollyhock leaf made it possible for the large conspicuous sori to drop away intact after a short treatment in potassium hydroxide, and the tangles of mycelium, which seemed to be produced more profusely than in the other species examined, attached in a thick mass beneath the groups of teliospores, were easily handled and stained. The hyphae were perhaps a little less irregular than in some of the other species, but the bulges and outgrowths at one side of the septa were characteristic of all the rusts studied.

Tranzschelia Pruni-spinosae, Coleosporium Solidaginis and *Melampsora Medusae* were all more difficult to study, but in each case enough free mycelium was obtained to observe the characteristic irregularities. Very short branches arising at one side of a septum and lying parallel with the main hypha in many cases gave the appearance of a clamp-connection in the process of formation, before the small outgrowth had fused with the old cell, but

further study showed that the branch was either always pointing toward the distal end of the hypha instead of arising from the new cell, or that its end was free and growing out from the parent hypha. In no case was one of these short branches found distinctly fusing with the adjacent cell.

Pucciniastrum Agrimoniae, because of its presumably primitive position among the rusts, was the one species of those investigated in which it was considered that clamp-connections were most likely to be found if their presence in the rusts were to be verified. Both fresh and permanent mounts of this species were carefully examined but no well-defined clamp-connections were observed. Structures giving the appearance of a half-closed partition wall, such as were illustrated by Voss and considered by him to be still open clamp-connections, occurred frequently in the material examined, but were necessarily



All drawing made with the aid of camera lucida and reproduced at a magnification of ×1000.

Fig. 1. *Pucciniastrum Agrimoniae*. a, characteristic bulge at side of septum; b, short hyphal branches resembling clamp hyphae but oriented toward tip of main hyphae; c, loops in larger hyphae similar to those regarded by Voss as partially formed clamps.

Fig. 2. *Coleosporium Solidaginis*. a, bulge at side of septum; the other figures show similar structures.

Fig. 3. *Melampsora Medusae*. Several hyphae showing short branches directed toward tips of main hyphae.

Fig. 4. *Tranzschelia Pruni-spinosae*. Upper hypha with bulge at septum; lower hypha with clamp-like branch.

Fig. 5. *Puccinia Malvacearum*. The hyphae are less irregular than in the other species but show similar protuberances.

given a different interpretation in the light of the present knowledge of clamp formation. They are to be regarded as small loops in the hyphae or as ordinary septa partially formed.

SUMMARY

The mycelium of five species of rust fungi, belonging to five different genera, three belonging to the Melampsoraceae and two to the Pucciniaceae, was examined for the presence of clamp-connections. Structures similar to those reported by Voss, and believed by him to be clamp-connections, were found in all species, but it was concluded that these structures do not represent true clamp-connections.

This investigation was suggested by Professor G. W. Martin and was undertaken in the mycological laboratory of the State University of Iowa.

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Book Reviews

COMPARATIVE VERTEBRATE ANATOMY. By Libbie Henrietta Hyman. University of Chicago Press, September, 1942. xx and 544 pp., 136 figures. $3.50.

For twenty-one years Hyman's "A Laboratory Manual for Comparative Vertebrate Anatomy" has enjoyed wide adoption and has introduced a host of eager young zoologists and pre-medical students to the field of comparative vertebrate anatomy. Paradoxically the wide sale of this manual dealing with vertebrate morphology has indirectly strengthened and enriched the sister field of invertebrate morphology, for the sale of this volume has enabled Miss Hyman "to live a life of singular freedom" and to devote herself exclusively to scientific writing and research. The splendid fruits of her work dealing with the invertebrates are too well known to be mentioned here.

Now, after two decades of work with the lower animal phyla, Miss Hyman has delved again into the vertebrate field and has emerged with a volume on Comparative Vertebrate Anatomy which may be used as both a text and a laboratory manual. For the most part, the laboratory directions are the same as those of her previous manual; it is the text which has been revised and expanded with Miss Hyman's characteristic thoroughness.

The book "aims to give the student a picture of a vast field full of controversial issues and unsolved problems, depending for their solution on future painstaking embryological and anatomical researches." As such it should serve as a stimulus to many students taking their first advanced course in zoology. One has but to consult the bibliography at the end of each chapter to realize that Miss Hyman's sources of information are both up to date and reliable.

Highlights of the volume include chapters dealing with: general considerations on animal form, the phylum chordata, essential features of lower types, adaptive radiation in gnathostomes, general features of chordate development, and a detailed section dealing with each of the vertebrate organ systems. Inserted in each of the latter sections are the laboratory directions for the dissection of the skate and spiny dogfish, necturus, turtle and alligator, pigeon, cat and rabbit.

Several illustrations have been added to supplement the expanded text and while some have obviously been hastily executed, they are on the whole well chosen and pertinent. Many more illustrations could be added profitably which would aid the student in digesting the concentrated textual material.

Inevitably errors are bound to creep into a work of this type. Those which the reviewer has noted have been few, and for the most part trivial. Miss Hyman falls into a very common error in discussing structural colors of feathers when she speaks of these colors being produced through "refraction" of light "by fine parallel striations." Of course light is never refracted when it is reflected back from a surface, rather it is *diffracted*. Moreover the light is not diffracted by parallel striations but by tiny particles or pores located in the barb in the case of blue feathers or by thin lamina or films in the barbules in the case of iridescent feathers. The statement that the feather barbules directed toward the calamus bear hook-like projections which "fit over and catch the flange-like extensions" of the barbules directed toward the feather tip is misleading. Actually, the barbules which bear hooks are those directed toward the feather tip—not those directed toward the calamus or quill. Figure 80 on page 224 was taken directly from the old manual with no changes apparently, and the submaxillary gland is still incorrectly labeled. The kangaroo rat is an unfortunate example of a marsupial on page 12 since in this country that name is more often applied to the saltatorial rodent *Dipodomys*. It should be pointed out in fairness to Miss Hyman that the above are all

minor errors which do not detract markedly from the true worth of the book. Moreover, it is especially gratifying to read such up to date discussions of the skeletal and muscular systems, to note that many of the stock evolutionary concepts have been altered to fit more recent findings, and to see a revised system of classification instituted at the beginning of the manual in which *Polypterus* no longer serves as the classical example of a Crossopterygian fish but is included with the ganoids, while the recently discovered coelacanth, *Latimeria*, now enjoys the title of the world's only living member of the Crossopterygii. *Branchiostoma* has been substituted for *Amphioxus* and *Saccoglossus* for the equally obsolete *Dolichoglossus*. In the light of the above changes it would seem desirable to substitute *Lepisosteus* for *Lepidosteus* when referring to the garpike.

Those students who are fortunate enough to be introduced to comparative anatomy on a scale and in the manner suggested by Miss Hyman's book should have no apologies to make for their background in this subject. Not only have representative vertebrates been carefully selected and directions for their dissection accurately and clearly given but the phylogenetic relationship of the vertebrate classes have been ably demonstrated in the light of present knowledge concerning their probable evolution. It should be clear to the stuudent, when the final pages of the book have been turned, that vertebrate morphology is still a field "full of controversial issues and unsolved problems" and that much yet remains to be done in this basic field on which many of the more recent avenues of zoological endeavor so heavily lean.—PERRY W. GILBERT, Cornell University.

COLLEGE ENTOMOLOGY. By E. O. Essig, The Macmillan Company, New York, 1942. vii + 900 pp., illust. $5.00.

Teachers of entomology have long felt the need of an up-to-date textbook on advanced insect taxonomy based upon modern concepts and written with a cosmopolitan outlook. This need has at last been well met by Essig's much delayed volume. Comstock's "An Introduction to Entomology" has for a long time been the "bible of entomology" for American students, even after forming a duo with Imms' "A General Textbook of Entomology." Now, with the advent of "College Entomology," there has been created a trio, for in this reviewer's opinion, Essig's work has not altogether replaced "Comstock" but instead supplements splendidly the earlier book. The reviewer may be justly criticized for his opinion; perhaps he stubbornly refuses to subjugate an old friend who has persistently and successfully been of lasting service to him. True, "College Entomology" is in many respects more accurate, more modern and more explicit. Thirty-three orders greet the teachers and students intent on using this book. Subfamilies in number have been elevated to families by specialists whose systems Essig has followed. All this is as it should be. Times change, ideas change, systems change—and so should teachers and students.

"College Entomology" is world-wide in its scope. This is not only refreshingly novel but it is also advantageous to the student whose horizon has been too limited. American insects are stressed; western forms are given no more than their due. Only the first two chapters of the book are non-taxonomic, dealing with anatomy and metamorphosis. The remaining thirty-four chapters are chiefly taxonomic—chiefly and not wholly because an abundance of interesting and frequently little known facts is interspersed properly. In "College Entomology" teleology recedes deeply into that mystical background to which it belongs, so deeply in fact, that one must search diligently before he can discover a single statement of purposive insect behavior.

Of outstanding interest, at least to the reviewer, are the tabulations of important anatomical characters which introduce nearly every hemimetabolous and holometabolous order and which apply to the external and internal morphology of adult as well as immature forms. The foundation of taxonomy is morphology, and hence an account of its structure is the best possible approach to the study of an insect order. Included in the book is a feature helpful to both teacher and student—the proper syllabication of ordinal names. Keys are plentiful and usable, and they seem to be accurate and

not overly complicated. The splendid figures are a distinct credit to the author's painstaking art. Chapter bibliographies are extensive and the references are well selected. Thorough indexes to authors and subjects emphasize the care Essig has taken to attain completeness in his book. Binding, paper, and print are above reproach.

American entomologists will welcome Essig's volume, and they will marvel at the fearless nature of the man who has done what none of his colleagues has apparently had the courage to do—to attempt the establishment of a dynamic rival for the old "bible of entomology." The book should awaken a simmering, but long dormant, interest among teachers and students who have always wished to keep abreast of the times entomologically, but who had never managed to do so.—A. C. COLE, JR., University of Tennessee.

STANDARDIZED PLANT NAMES. A Revised and Enlarged Listing of Approved Scientific and Common Names of Plants and Plant Products in American Commerce or Use. Prepared for the American Joint Committee on Horticultural Nomenclature by its Editorial Committee Harlan P. Kelsey and William A. Dayton. J. Horace McFarland Co., Harrisburg, Pa. 1942. xv + 675 pp. $10.50.

Compared with this beautiful volume the first edition (1923, Salem, Mass.) appears modest with its smaller format and page number (546). Yet it is not likely that the increase in size, page number, etc. is due solely to commercial expansion or wider use of plant products and greater horticultural activity. The Committee obviously labored to make this edition as complete as possible, a task in which many leading botanists participated. A few examples may illustrate the thoroughness of the work.

Nearly fourteen pages of three columns print are needed for the genus Chrysanthemum; of these only half a page is required for the scientific names, about a page for the names of originators and introducers, whereas the remaining ones list the common names and the names of horticultural varieties (clons). Twenty pages are devoted to the genus Paeonia, almost thirty to Rosa, lumber trade names are found on pp. 342-373 and drug plant names on pp. 175-202. Other headings are range plants (pp. 509-523), economic plants (new feature) with sixteen subheadings ranging from beverages to waxes, waterlily genera, poisonous plants, economic cryptogams (list is rather short), fruits and edible nuts, weeds, etc. A list of plant patents through July 1, 1941 is included (pp. 455-457).

S. P. N. is not entirely without surprises. New terms such as polybrid, ortet and heterogen either make their début or are apparently recommended for adoption. According to the definition given, a chimera exhibits characters of both stock and cion, caused by the "blending of the tissues of both." Although many sources of names are cited in the Preface, they were not used to the fullest extent and the nomenclature of certain species has thus not been brought up to date. A list of "vines" might be as useful as many other headings now included. Certain common names are missing, e.g., Mexican Potato. As printed here many common names are harder to pronounce than scientific ones, should the reader elect to follow the rules of pronunciation with which he may be familiar. Regardless of these shortcomings, S. P. N. is a book of immense practical value and as such an indispensable aid.—THEO. JUST.

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